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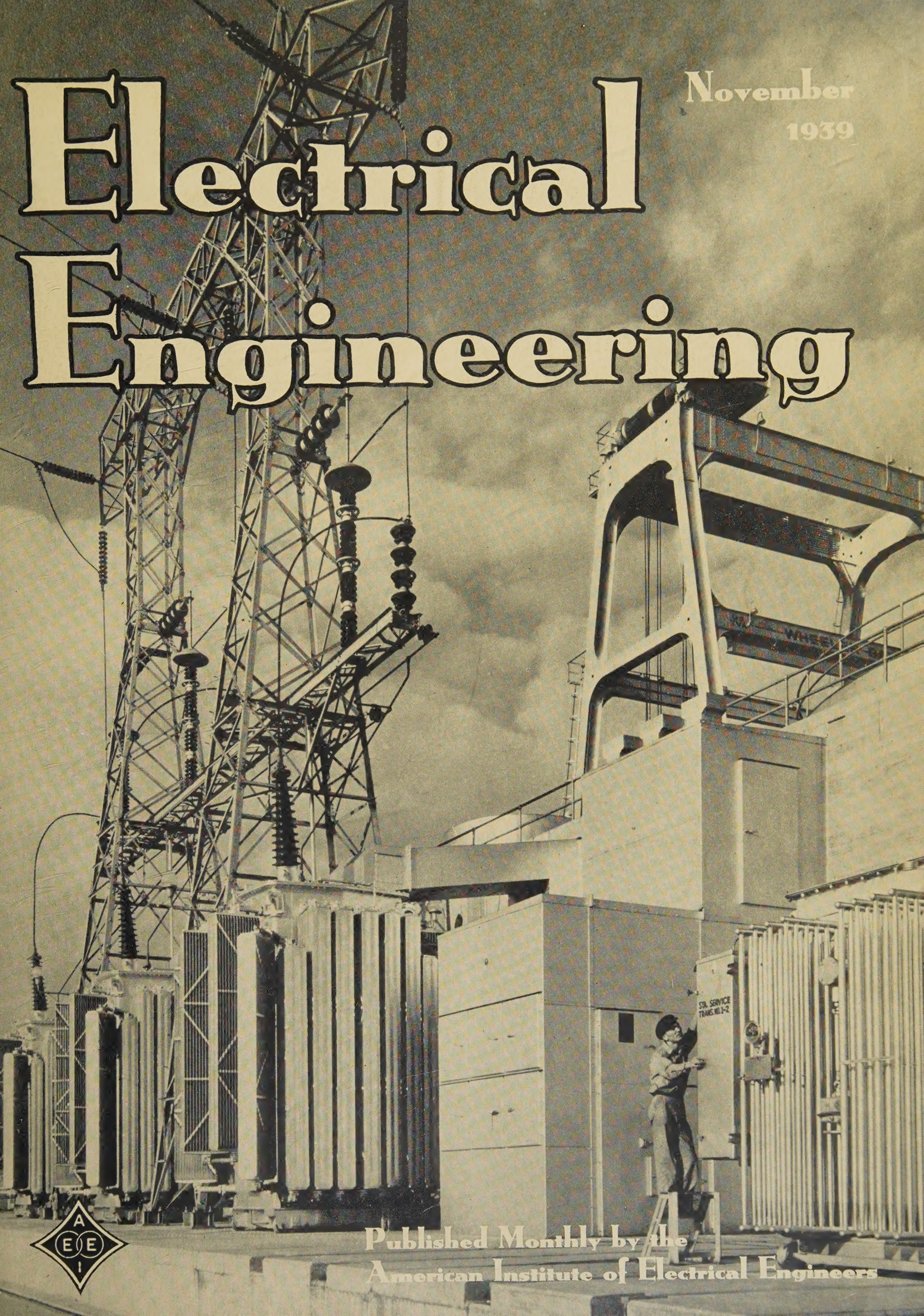

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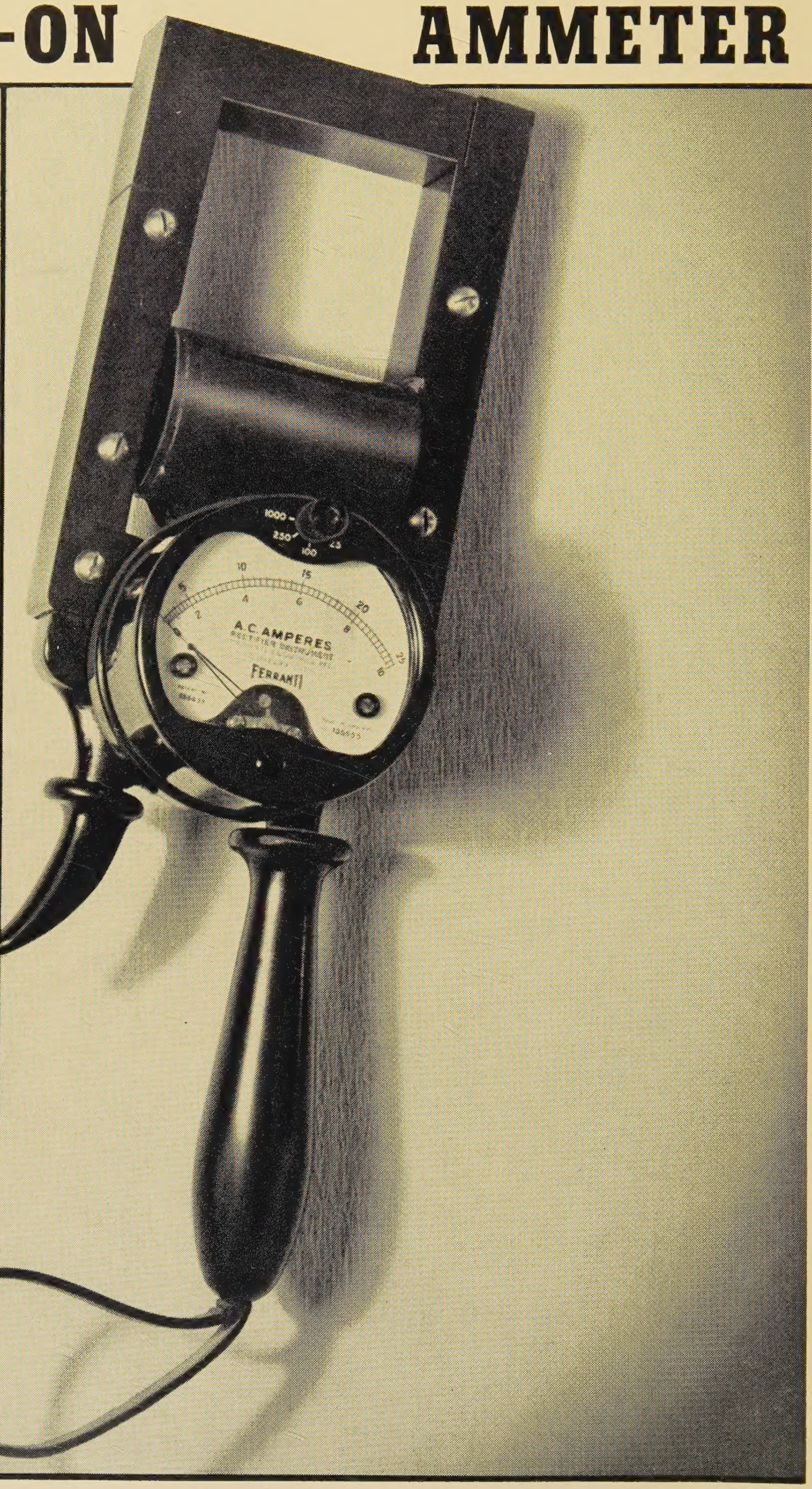

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Transactions Section *(Follows EE page 494; a preprint of pages 563–610 of the 1939 volume)*

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F. MALCOLM FARMER, President — H. H. HENLINE, National Secretary

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High Lights

Petersen Coil. The effectiveness of the Petersen coil in extinguishing line-to-ground arcs on a transmission system ordinarily is attributed to the fact that the current in the arc is kept at a low value. Another factor of perhaps greater importance is that characteristic of the Petersen-coil system which results in a very low rate of rise of recovery voltage across the arc terminals (*Transactions pages 576–81*). To reduce insulator flashovers on a 66-kv system, Petersen coils were chosen as the most practical method in the given situation; experience during the first year of operation shows that two-thirds of all faults were cleared without circuit-breaker operation (*Transactions pages 568–75*).

Nominations. Some members of the AIEE have remarked that its nomination and election procedure is "cut and dried" and that they have little if any voice in selecting the Institute's national officers. However, the Institute's by-laws contain provisions whereby the members, either individually or through their local Section organizations, may suggest nominees directly to the national nominating committee and other provisions whereby independent nominations may be made (*page 484*). On the facing page, President Farmer suggests some ways in which members may utilize the existing provisions to fuller advantage.

Measuring Watts and Vars. An instrument of negligible burden to measure watts and vars for use with a network analyzer has been built using an electrodynamic wattmeter, a negative-feedback vacuum-tube amplifier, and a phase-shifting network. The principle of instruments of this kind has other important applications in the field of electrical measurements (*Transactions pages 593–8*).

Vertical-Shaft Generators. Like other electrical machines, the design of vertical-shaft generators is complicated by interrelated electrical, mechanical, and thermal aspects and their usually conflicting requirements. The problem is further complicated by the fact that each machine must be "tailor made" to suit the requirements of individual hydroelectric projects (*pages 469–79*).

Emergency Ratings. Reduction of fixed costs of supply offers the major opportunity for improving the competitive position of electricity. One step in the solution of the problem is increased load ratings, mostly for cables. Maximum emergency loads should not affect the ability of the system to operate satisfactorily under extreme conditions (*Transactions pages 599–610*).

High-Speed Relaying. High-speed circuit breakers with operating times of eight cycles and one-cycle relays were introduced about 1930. Replies to a questionnaire circulated among typical operating companies revealed both satisfactory operation and some difficulties that were experienced in practical operation (*Transactions pages 588–92*).

Lightning Research. Various tests show that shattering, bursting, and explosive effects are caused largely by the high-current short-duration component of the lightning stroke, whereas fires, heavy fusion of metal, fulgurites, and extensive burning result largely from the low-current long-duration component (*pages 466–8*).

District Meetings. Reports of two AIEE District meetings, one held by the Great Lakes District at Minneapolis, Minn., and the other by the Middle Eastern District at Scranton, Pa., are included in the news section of this issue. Each meeting included a Student Branch convention (*pages 480–1 and 482–3*).

Rectifiers. By various means now available, the output of mercury-arc rectifiers may be regulated for flat voltage control, under- and overcompound voltage control, voltage control and current limiting, current control, and control suitable for other special applications (*Transactions pages 563–8*).

Electricity and Search for Oil. Electricity plays a vital part in several of the commonly used methods of locating deposits of oil hidden beneath the earth's surface. In addition to the strictly electrical methods, electricity provides the means of recording the results of other methods (*pages 455–62*).

News 480

New Transmission Line. Simple and time-tested features form the basis of design of the recently completed 233-mile 220-kv line connecting the power plant at Boulder Dam with the Southern California Edison Company system (*pages 463–5*).

ECPD Meeting. At its seventh annual meeting, the Engineers' Council for Professional Development announced the accrediting of some 680 curricula in 140 engineering schools (*page 485*).

Mutual Induction. One of the causes of mysterious behavior of ground-current relays on parallel transmission lines is the induction of current in one line by a fault in the other line (*Transactions pages 582–8*).

Polarized Light. Increasing applications of polarized light in engineering are predicted in an article which reviews the nature and properties of the phenomenon (*pages 450–4*).

Hoover Medal. Joint engineering societies award, the Hoover Medal for 1939 will be presented to a prominent past-president of the AIEE (*pages 484–5, 489*).

Coming Soon: Among special articles and technical papers now undergoing preparation for early publication are: an article describing the unique conveyer that transported spectators through the General Motors "Futurama" at the New York World's Fair, by James Dunlop and W. T. White; an article reviewing operating performance of the low-voltage a-c network in Philadelphia, Pa., during the 12 years since it was established, by P. W. Crosby (A'27); an article outlining the present status of progress in electrical insulation achieved by physicists, chemists, and electrical engineers by L. J. Berberich (M'36); a paper on economical loading of high-voltage cables installed in underground subway systems by E. R. Thomas (M'30); a paper describing experience with ultrahigh-speed reclosing of high-voltage transmission lines by Philip Sporn (F'30) and C. A. Muller (M'36); a paper on ignitrons for the transportation industry by J. H. Cox (A'25) and G. F. Jones; a paper describing improvements in the construction of capacitor-type bushings by A. J. A. Peterson (M'30); a paper on line problems in the development of the 12-channel open-wire carrier system by L. M. Ilgenfritz (M'39), R. N. Hunter (A'39), and A. L. Whitman (M'30); a paper describing some applications of the type *J* carrier system by L. C. Starbird (M'35) and J. D. Mathis (A'28); a paper on out-of-step blocking and selective tripping with impedance relays by H. R. Vaughan (A'31) and E. C. Sawyer (A'39); and a paper on the dielectric strength of porcelain by P. L. Bellaschi (M'34) and M. L. Manning (A'36).

Subscriptions—$12 per year to United States, Mexico, Cuba, Porto Rico, Hawaii, Philippine Islands, Central and South America, Haiti, Spain, Spanish Colonies; $13 to Canada; $14 elsewhere. Single copy $1.50. ¶ Address changes must be received by the fifteenth of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge. ¶ ELECTRICAL ENGINEERING is indexed annually by the Institute, weekly and monthly by *Engineering Index*, and monthly by *Industrial Arts Index;* abstracted monthly by *Science Abstracts* (London).

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A Message From the President

Membership Participation in AIEE Elections

THERE appears in this issue of ELECTRICAL ENGINEERING the usual annual notice inviting the membership to suggest to the national nominating committee candidates for the various national offices that will become vacant July 31 next. It recalls the comment occasionally heard that our elections of national officers are more or less "cut and dried," that the rank and file of the membership can have little influence in the selection of our officers, and that, as a consequence, our elections are not carried out in the completely democratic spirit contemplated by the prescribed procedure. A review of our election machinery therefore is opportune at this time.

Our procedure may be summarized briefly as follows:

1. The executive committee of each of the ten geographic Districts designates a member of the national nominating committee.

2. These ten members and five members of the board of directors chosen by the board constitute the official national nominating committee.

3. The membership at large, through a notice in ELECTRICAL ENGINEERING, is invited to suggest candidates for the various offices to the nominating committee.

4. The executive committee of each District in which the term of the vice-president is to expire makes the nomination for that office.

5. The nominating committee, at a meeting at headquarters, selects and recommends to the membership one candidate for each office to be filled, including in its list the names of the nominees for vice-presidents as selected by the District executive committees. The list of such names constitutes the official ballot upon which the members vote. (The nominating committee may designate more than one candidate, but to date that has never been done.)

6. Provision is made for the inclusion on the official ballot of the names of additional candidates, provided each such candidate is proposed by not less than 25 members. Thus opportunity is afforded for independent selections where there is any appreciable disagreement with those of the nominating committee.

It thus is assumed that 15 men qualified with respect to geographic distribution and knowledge of their fellow members are likely to make wiser selections in conference than could 17,000 men acting independently. This group is in a far better position to give consideration to and properly weigh the many factors that are involved in considering candidates, such as professional standing, technical or other contributions to the advancement of the art, service to the profession, service to the Institute, geographic distribution, and distribution with respect to the branches of the art.

This election machinery would appear to be adequate to obtain a reasonably wise selection of officers by a democratic process. It is very doubtful, however, if its provisions are being fully utilized to enlist the interest and aid of the greatest number of our members in the selection of candidates. Therefore, the following suggestions are offered:

1. That the executive committee in each *geographic District* invite the executive committee of each *Section* in the District to consider and recommend to the District executive committee:

(*a*). A candidate for the District representative on the national nominating committee—the recommendation to be accompanied by a brief statement of the qualifications of the proposed candidate.

(*b*). A suggested candidate (or candidates) for the presidency.

(*c*). In the vice-presidential election years, a suggested candidate (or candidates).

2. That the District executive committee, having before it the foregoing suggestions, consider them together with their individual suggestions and:

(*a*). Select a member of the national nominating committee (together with an alternate) to represent the District.

(*b*). Select a candidate for president whom the District representative on the nominating committee would be instructed to place in nomination at the meeting of the nominating committee.

(*c*). In vice-presidential election years, nominate a vice-president for the District.

3. That more members respond to the invitation to submit individual suggestions directly to the national nominating committee.

Compliance with these suggestions would enlist the interest of a greater number of members in the election procedure which in itself is much to be desired. A further and more important result would be that the 15 members of the national nominating committee, functioning as judges on behalf of our 17,000 members in the selection of candidates for the national offices, would have before them a larger number of suggested candidates. It is only reasonable to conclude that the greater the number of proposals considered, the wiser is the committee's final selection likely to be, particularly when many of them are already the considered selections of other groups.

F. Malcolm Farmer

Polarized Light

L. W. CHUBB
FELLOW AIEE

With the development of practical polarizing sheets, polarized light, long known and employed by science, is being given increasingly wide use in engineering and industry. Its applications in the study of stresses, in photography, stereoscopic motion pictures, vehicle lighting, and display lighting, are among those mentioned by this author, who reviews polarized light for the engineer.

POLARIZED light was discovered in the 17th century by Huygens and has been intensively studied and used in scientific work. Engineers, however, seem to remember little about the polarized light studied in high-school or college physics, and infrequent engineering application or use is made of it. The object of this article is to refresh the memory of the engineers with respect to polarized light, by describing in a simple engineering way its nature, properties, and uses.

Nature of Light

The nature of light has been a speculative and controversial subject among philosophers for centuries. Experimental evidence has caused the prevailing theory of the nature of light to change back and forth at least four times between a corpuscular emission and a wave phenomenon in an imaginary elastic medium, which we call the ether. There have always been some experimental facts which could not be satisfactorily explained by either theory. Today, the physicist seems resigned to the corpuscular nature of light, although certain difficulties still exist. The modern physical theories, involving quantum mechanics and relativity, teach us that light may be assumed to consist of a myriad of projectiles which we call photons or quanta of gamma radiation. They travel through space at a constant velocity.

Since a flux of either light particles or vibrations in the ether can be shown to have the characteristics of waves, we may more easily treat the subject as wave phenomena just as we treat electrical phenomena as waves even though we know that an electrical current consists of charged corpuscles of electricity—electrons and ions.

Kinds of Wave Motion

There are different types of wave motions which are readily recognized. In the first place, there are longitudinal waves, such as sound waves through gases, liquids, or solids, in which the medium vibrates to and fro in the direction of propagation. Because of the elastic characteristics of the medium, waves of compression and rarefaction travel away from the sources at a speed dependent upon the elasticity and the density of the medium.

Second, we have surface waves, such as those on deep water, in which the particle of the medium moves in a circle as the waves progress. At the crest of the wave, the water moves forward; as the wave passes, the water falls; in the trough, it is moving backward; and as the next crest approaches, it rises and moves forward again. In this case, we do not depend upon the elasticity of the medium but upon its density and forces of restitution.

The third familiar wave is what is called a transverse wave, in which the particles of the transmitting medium vibrate at right angles to the direction of propagation. If we shake the end of a stretched rope or wire, waves will be propagated along it by the transverse motion of the flexible yet inextensible rope. Light, radio, heat, and all other invisible waves which make up the complete electromagnetic radiation spectrum may be explained by this type of wave with transverse vibrations.

Many of the phenomena of light can be explained by the first form of longitudinal wave in an elastic medium; however, the transverse vibrations must be assumed to explain all phenomena, especially those dealing with polarized light. It was the discovery of the "one-sidedness" of polarized light which pointed the way to the transverse-wave theory for light.

Properties of Light

Light (including heat, radio, and the invisible radiations in the complete spectrum) has many interesting properties. Its wave frequency determines its color in the visible spectrum (other properties in the invisible ranges). All such waves of different frequency can be combined, separated, transmitted quite independently in crisscross fashion in homogeneous space, without any interference. They may be refracted, reflected, transformed, absorbed, have their speed and phase changed, made to interfere under certain conditions. Besides being the means by which we see, light is essential in many ways. It makes the vegetation grow and produces photochemical and thermal changes. It is the primary cause of the winds, the rain, the ocean waves, and the carrier of all direct and stored energy from the sun to the earth.

Forms of Polarized Light

There is a difference between ordinary light and polarized light. In ordinary light, the transverse vibrations are random or change angle or azimuth very rapidly.

Based on a demonstration talk given before the AIEE New York Section, New York, N. Y., March 9, 1937, under the auspices of the AIEE committee on production and application of light.

L. W. CHUBB is director of research laboratories, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

On the other hand, polarized light may be said to consist of transverse-wave vibrations in which there is some regular motion.

There are three typical forms of polarized light: plane-polarized light, elliptically polarized light, and circularly polarized light.

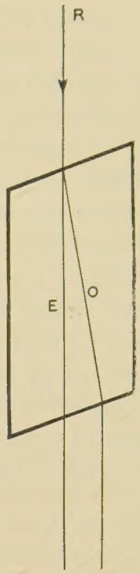
Let us return to our horizontal stretched rope to illustrate these forms of waves. If we shake the free end of the rope transversely up and down, crosswise, and at all diagonal angles, waves of an irregular form will be propagated along the rope and illustrate the random nature of ordinary light. If next we shake the free end of the rope up and down, the waves propagated along the rope will be in a vertical plane and illustrate the plane-polarized waves. Elliptically and circularly polarized waves may be illustrated by shaking the free end in an elliptical or circular path respectively, propagating regular waves along the length of the rope. Each particle of the rope will describe a plane, ellipse, or circle as the case may be, but successive parts will have different time phase.

One may question whether the circular motion of the rope is a transverse vibration. Let us answer this by saying that the motion can be resolved into two linear transverse vibrations at right angles and in quarter-space phase. This method of resolving the wave motions into two vibrations at right angles is familiar to the engineer and will be of help in understanding what is to follow.

We may therefore reconsider the examples given, stating them in what we may call vertical and horizontal polyphase components. Plane waves are produced by a vertical and horizontal vibration of the same frequency and in time phase. The azimuth of the combined linear motion depends upon the relative amplitude of the two components. Elliptical waves are produced by the combination of vertical and horizontal vibrations of the same frequency and different in phase. Circular waves result from vertical and horizontal motions of the same frequency, equal amplitude, and in quadrature time phase. These relations combining quadrature harmonic motions are so well understood by engineers that no diagrammatic illustration is considered necessary.

Our single rope might be said to represent a single ray of light. To visualize a pencil of rays a great many parallel ropes should be assumed and the waves propagated along all of them together by the simultaneous transverse motion of their free ends.

In an electrical circuit, currents of different frequencies and phases may be simultaneously transmitted. The same is true of light, and we may suppose each of the vertical and horizontal component vibrations to consist of different frequencies to represent the different color components.



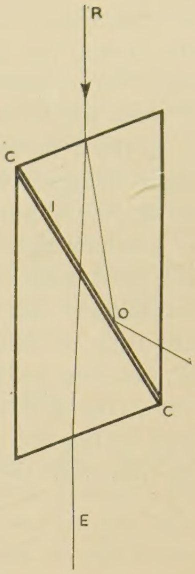


Figure 1 (left). Diagram of a crystal of Iceland spar in section

Figure 2 (right). Diagram of the Nicol prism, the commonest means of polarizing light by double refraction

Methods of Polarizing Light

It has been pointed out that common light vibrates randomly at all azimuths, transverse to the direction of propagation. To plane-polarize light, it is necessary, then, in some way to resolve all the component vibrations into one plane. With the rope, suppose it extends between two pickets of a fence, so that it can move only vertically. Any irregular motion given to the rope will be propagated to the fence and only the vertical components of the motion will proceed beyond the fence. We may then say that the waves beyond the fence are plane-polarized.

There are several ways of polarizing light to get the necessary regular motion of vibration.

Crystals with their atomic lattice are like the picket fence, but, instead of allowing vibrations in one plane only, the most common crystals will allow transverse vibrations to pass through in planes parallel to and at right angles to the optic axis, or in the direction of the atomic lattice rows. Beyond the crystal, or birefringent material, as it is called, the two quadrature wave components will combine vectorially again and proceed as before.

Certain crystals, of which tourmaline is a good example, transmit the two vibrations with unequal absorption. One ray is strongly absorbed and the other transmitted quite freely. With a suitable thickness of tourmaline crystal, we may substantially absorb one vibration and the transmitted light will be plane-polarized.

This then is one way to plane-polarize light, by differential absorption in a dichroic crystal.

Certain organic crystals, such as iodo-sulphate of quinine, have this property of absorbing one vibration much more strongly than does tourmaline. A thickness of 0.0002 inch will give practically complete polarization of visible light. Certain other crystals, known as double-refracting crystals, such as calcite or Iceland spar, have the property of refracting the component vibrations differently so that they may be separated.

Figure 1 shows a crystal of Iceland spar in section. When a ray of common light *R* is transmitted into such a crystal, two refracted beams *O* and *E* arise. They are both plane-polarized and their planes of polarization are at right angles to each other. If one of these rays can be discarded, the transmitted light will be plane-polarized.

Figure 2 shows the Nicol prism, the most common means of polarizing light by double refraction. The crystal is cut along the line *CC;* the faces polished and cemented together again with Canada balsam. The index

of refraction of the balsam being lower than the index of the crystal for the more oblique ray O, it will cause the ray O to be totally reflected and thus rejected. The ray E alone will be transmitted as plane-polarized light.

A third method of polarizing light is by reflection. Light obliquely incident on a transparent surface is partly reflected and partly transmitted. In figure 3, the ray SO of common light is split into a reflected beam OR, and a refracted beam OT, which is transmitted. As the angle of incidence θ and the angle of refraction ϕ are varied, the ratio of reflected to transmitted light increases until at glancing incidence all of the light is reflected. Also, the component vibrations in the reflected light normal to and within the plane of incidence (ROS) change in ratio so that when the tangent of the angle of incidence ($\tan\theta$)

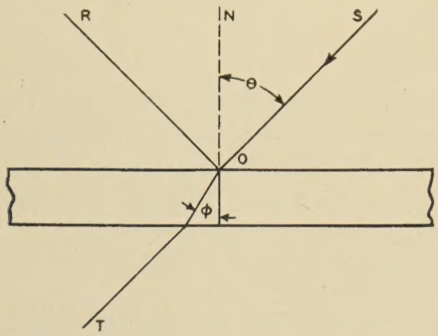


Figure 3. Diagram showing how light can be polarized by reflection on a transparent surface

is equal to the index of refraction of the reflecting substance, substantially all of the reflected light is vibrating in a plane normal to the plane of incidence.

Figure 4 shows the light reflected from a polished glass surface. Curve A shows the percentage of the reflected-light components vibrating normal to the plane of incidence and curve B shows the percentage of reflected-light components vibrating in the plane of incidence, for a reflecting surface having an index of refraction of 1.5. It will be noted that all components vibrating in the plane of incidence substantially vanish at 56 degrees, so that at this angle we have plane-polarized light reflected. This critical angle, called Brewster's angle, is the one for which the tangent is equal to the index of refraction.

It will be noted that only 15 per cent of the light vibrating in the one plane is reflected at the critical angle. Since only half of the intensity of common light is due to components vibrating in this plane, the useful polarized light from a single surface amounts to only 7.5 per cent of the incident light. To overcome this limitation, it is customary to use multiple plates of glass in order to obtain reflections from the front and back surfaces of each.

These are the three most common means of plane-polarizing light; however, there are others, one of which may be mentioned. Very small particles in scattering light give a predominance of polarized light at right angles to the incident beam. Thus the ring of blue sky in direction normal to the direction of the sun's ray is almost completely plane-polarized. Also the rainbow is polarized.

Before showing how elliptically and circularly polarized light are produced, it is well to call attention to certain simple conventions and recall some facts about light and optics. By convention, the plane of polarization is at right angles to the direction of vibration of the polarized light. When a ray strikes a surface, the angle of incidence is equal to the angle of reflection. When a ray of light passes from a less dense medium (air) into a more dense medium such as glass, the refracted ray in the glass is turned toward the normal (see figure 3). The index of refraction is the ratio of the sine of the angle of incidence to the sine of the angle of refraction. In figure 2

$$\text{Index of refraction} = \frac{\sin\theta}{\sin\phi}$$

Light waves are retarded or slowed in velocity in dense media. The wave velocity is the velocity in space divided by the index of refraction of the given substance. This means that the slower waves (at the same frequency) must have a correspondingly shorter wave length.

Crystals and certain transparent substances with a grain, such as cellophane, have different indices of refraction for vibrations normal to and parallel to the axis or grain of the material. (Some crystals known as biaxial have three indices.)

Just as currents of equal frequency and different phase must be added vectorially, the vibrations of light of different space and time phase must be treated vectorially.

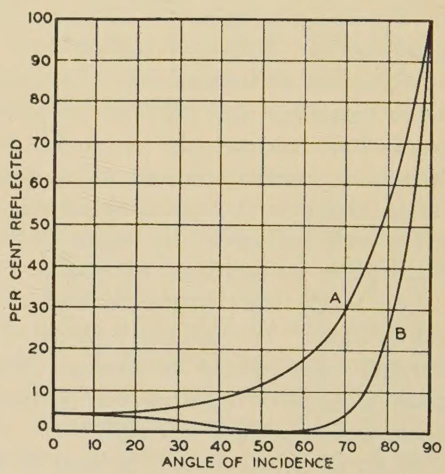
Intensity of light is proportional to the square of the amplitude of vibration, just as energy dissipated in a conductor is proportional to the square of the current.

Assuming all light vibrations resolved to two components at right angles, the foregoing considerations make it

Figure 4. Graph indicating reflection of light from a polished glass surface, index of refraction, 1.5

Curve A—Reflected-light components vibrating normal to plane of incidence

Curve B—Reflected-light components vibrating in plane of incidence



simple to understand the production and properties of circularly and elliptically polarized light.

Instead of a rope having a round section and an equal flexibility in all directions, suppose we assume a stretched wire of rectangular section, with the greater dimension vertical and the wire so long that there will be no waves reflected back from the fixed end. If we shake the free end up and down, there will be greater stiffness and the vertical waves will travel faster than if we shake it horizontally. Suppose now we shake the end at constant frequency, diagonally at 45 degrees. This is the same as a simultaneous vertical and horizontal vibration of

equal amplitude. At the hand the motion will be a line, both vertical and horizontal motions in the same time phase. As we proceed along the wire, the horizontal components of vibrations, due to their slower velocity, will lose in time phase and the transverse motion of the wire will become an ever-widening ellipse, until the point along the wire is reached where the horizontal waves have lost just a quarter of a cycle. Here the wire will be found to be describing a circular path. Further change in phase will result in an elliptical motion with its major axis in the other diagonal and when the phase difference is one-half cycle, the motion will again be a straight diagonal line at right angles to the linear motion of the hand. At three-fourths-phase difference, the circular motion will again appear, but the direction of rotation will be opposite to that at the quarter-wave position.

Figure 5 shows graphically the path of the wire in a plane normal to the wire. There are, of course, many individual wave crests between these points along the wire where the particular phase differences exist.

Now since some crystals and other birefringent materials have different indices of refraction and different speed of wave propagation in planes perpendicular and parallel to the optic axes, this same phase difference between the right angle component vibrations can be obtained and plane-polarized light readily changed to circular or any form of elliptical polarization.

If plane-polarized light is normally incident upon a crystal plate and the transverse vibrations of the light are parallel to or at right angles to the optical axis of the crystal, the light will be transmitted and emerge as plane-polarized light in the same azimuth. It will suffer only certain phase retardation depending upon the thickness and index of refraction.

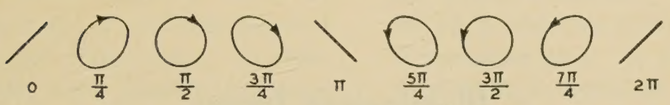


Figure 5. Diagram of vibrations of a stretched wire of rectangular section, shaken diagonally at 45 degrees in constant frequency

If now the transverse vibrations of the incident plane-polarized light enter the plate at an azimuth of 45 degrees, they will be split into two components vibrating parallel to and at right angles to the axis.

These components will be of equal amplitude, but since they will travel at different velocity, there will be progressive difference in phase. If the thickness of the crystal is such that the relative retardation is just one-fourth cycle, they will emerge into the homogeneous medium, air, as circularly polarized light. This is what is called a quarter-wave plate, and is used to convert plane-polarized to circularly polarized light.

To go further, suppose the plate to be twice as thick so that it produces one-half cycle of relative retardation; it will be a half wave plate and the light will emerge as plane-polarized light shifted 90 degrees in azimuth.

It is evident that for intermediate thicknesses elliptically polarized light will be produced.

This consideration of retardation of a single frequency or wave length seems simple enough, however, for other wave lengths the relative phase retardation will be quite different for the same thickness. What is a true quarter-wave plate for yellow light, for instance, will not be a quarter-wave plate for red or blue. Other means involving internal reflection, such as Fresnel's rhomb, must be used when working with white or mixed light, in order to obtain equal phase shift for all wave lengths.

Properties and Uses of Polarized Light

From the foregoing it is evident that light passing through a polarizer will have its vibrations changed to parallel planes and this light will readily pass on through another polarizer which is similarly oriented, or said to be optically coincident. If now the second polarizer is rotated around the beam as an axis, the component of light passing through will be proportional to the cosine of the angle of rotation, and when it has rotated 90 degrees, all of the light will be cut off. Since light intensity is proportional to the square of the amplitude of vibration, the intensity will vary as cosine square giving a variation of transmitted intensity, as shown in figure 6.

This feature is of great value in the use of polarized light and is the means by which we may test for any rotation of the plane of polarization or may sort out selectively different color components which may be polarized in different planes.

Polarized light is rotated by certain substances. Thus a sugar solution will rotate the plane in proportion to the strength of the solution and the length of path traversed. This is called *specific rotation.*

Polarized light is also rotated in other substances when a magnetic field traverses the substance in the direction of the passage of light. This is called *magnetooptic rotation,* and although not generally used, has many possible uses now that practical polarizing sheets have been made available.

Still other substances traversed by polarized light become more or less birefringent when subjected to electrical stress. This is called *Kerr effect* and may be used for light valves, to modulate a beam of light in proportion to a voltage wave.

Solid transparent and optically inactive substances,

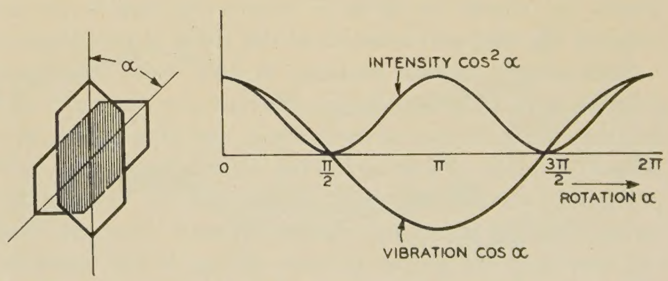


Figure 6. Diagram showing variation in intensity of a beam of polarized light transmitted through a second polarizer which is rotated around the beam as an axis

such as glass, celluloid, and bakelite, when subjected to stress obtain birefringence; and with polarized light, enable one to tell by the fringes which appear the stress conditions in the material. This is called *photoelasticity* and is most valuable in working out stress problems, using transparent models, which have the same shape and load distribution as the machine part or structure which is under stress analysis. The same phenomenon shows the internal stresses in improperly annealed glass products.

It was shown in connection with figures 3 and 4 that reflected light from a smooth surface is strongly polarized. This glancing-off light is what is called specular reflection or glare; it has the color characteristics of the original source rather than those of the reflecting surface. Instead of helping us to see the object from which it is reflected, it interferes with vision.

Figure 3 illustrated the reflected and transmitted ray for a transparent surface. When we have an opaque surface (let us assume a blue china plate), the specularly reflected light glances off by showing shine, glare, and high lights characteristic of the source of light. Thus the high lights produced by the reflected image of the window or electric lamp are white, not blue. The vibrations that are refracted into the surface go to illuminate the substance. They are partly absorbed and partly reflected as scattered light and it is by these components that we discern the object—its true color, texture, and so on.

The glare which is polarized can be effectively eliminated by observing the object through a polarizer properly oriented. With polarizing spectacles, this is the secret of the selective reduction of glare and shine without a similar reduction in the scattered radiation by which we see.

In photography, polarizers may be used before the camera lens to filter out the sky glare which is polarized, and get other artistic effects. In studio work, the objects may be illuminated by polarized light and the camera lens covered by a polarizer at quadrature azimuth, thus eliminating all disagreeable high lights and giving photographs that require no retouching for reproduction.

Another promising use of polarized light is in vehicle lighting. If all cars project polarized light vibrating in a plane 45 degrees to the horizontal and the road is viewed through a polarizing screen that is optically coincident, it is possible to see the reflected light from your own headlights, but there will be no glare from opposing lights similarly equipped. The opposing lights will be optically crossed with your viewer, because the opposing car is traveling in the opposite direction. The arrangements are shown in figure 7, where the double arrows indicate the diagonal azimuth of the plane of polarization.

Stereoscopic motion pictures in true color are made possible with polarized light. Pictures for the right and left eyes are projected alternately or simultaneously, with polarized light. Pictures for the separate eyes use light polarized mutually at right angles and by viewing the screen through polarizing glasses properly oriented, each eye sees only its proper picture, giving a true three-dimensional effect.

Polarized light of two or more colors polarized in different azimuths may be mixed and selectively sorted out, so as to give advertising signs and display devices of various color combinations. It may be used for secret signaling and telephonic communication through a beam of light, and in many ways for control and position indication.

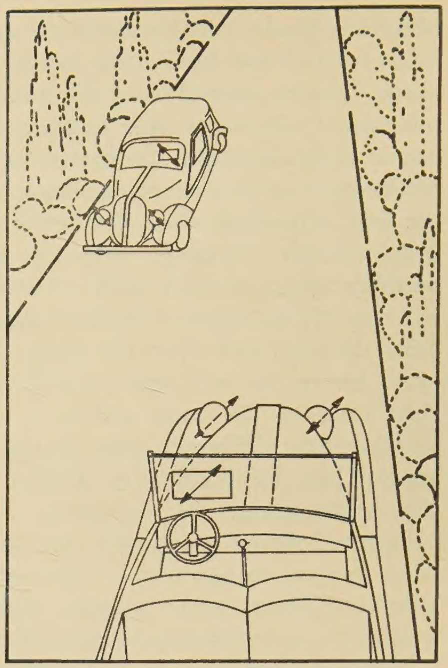


Figure 7. Diagram illustrating the use of polarized light for motor headlights

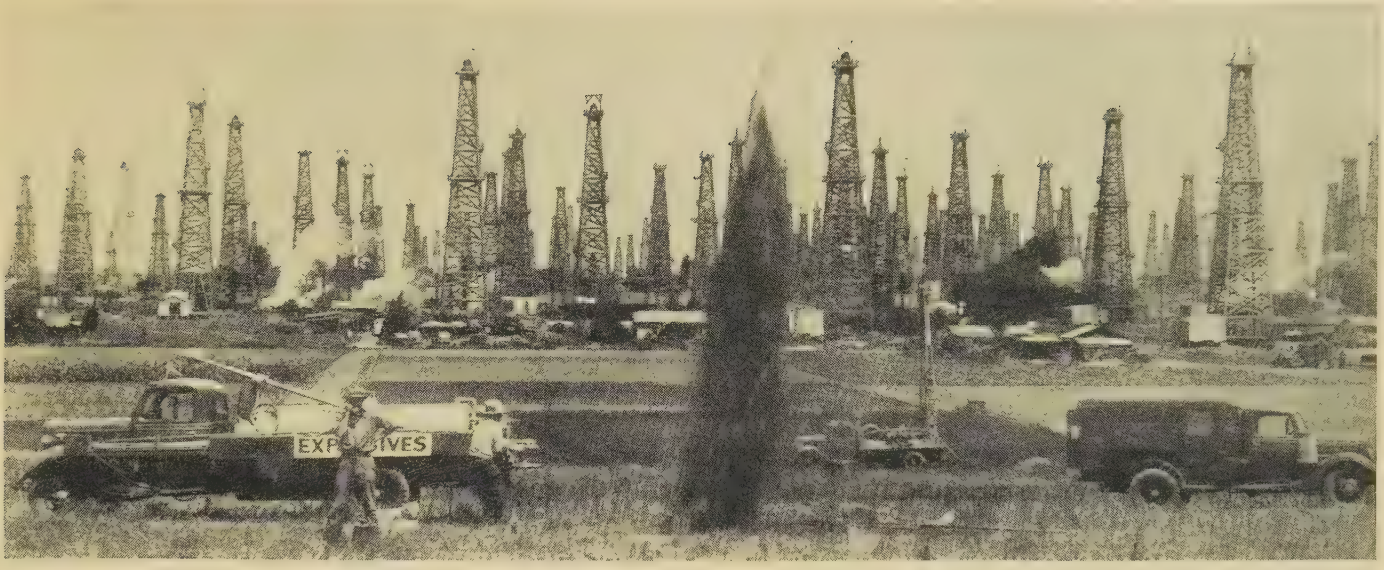
In the past very little engineering application has been made of polarized light because efficient polarizers of large aperture were not available. In recent years, however, absorption polarizers in sheet form have been developed and provide a means by which the engineer may make use of the many unique properties of polarized light.

Illumination Notes*

Light and Safety. Records kept by L. J. Samson, city traffic engineer of Chicago, Ill., show a large dividend in safety on the investment for lighting dangerous intersections with sodium-vapor lamps. For the year following the installation of the lamps, in November 1937, as compared with the preceding year, night accidents dropped from 95 to 40, or 58 per cent; the number of persons injured from 43 to 14, or 67 per cent; and property-damage collisions from 61 to 28, or 54 per cent.

A recent report by E. R. Sherbaum, electrical engineer, New Jersey State Highway Department, shows that for the first 11 months of 1938, on highways where modern lighting systems had been installed, fatalities from night driving decreased 37 per cent (from 245 to 154) as compared with the same months in 1937. On those same highways, the number of fatalities from daytime accidents remained constant (136 as against 137). In counties where lighting installations are not completed, the fatalities from night accidents also remained practically constant (23 as against 22).

*Contributed for the AIEE committee on production and application of light by L. A. Hawkins (A'03, M'13) executive engineer, research laboratory, General Electric Company, Schenectady, N. Y.



Electricity Aids in the Search for Oil

DANIEL SILVERMAN
ASSOCIATE AIEE

The apparent magic that created great oil fields out of grassy marshlands is not a product of the divining rod but the result of the application of scientific principles involving the fundamentals of the science of applied geophysics. A review of the various methods of geophysical prospecting for oil, in which electricity has played a large part, is presented here. In addition to strictly electrical methods, electrical measurements provide a means of recording the results of other methods.

EVER since man has made use of the earth's mineral products, the thought has been in his mind that it should be possible to predict, by some means or other, the location of mineral deposits hidden from view. In olden days such possibilities were placed altogether in the realm of magic, although even today, the divining rod is thought by some to possess the supernatural faculty of locating all kinds of mineral deposits. The apparent magic that created the great oil fields that rise so suddenly out of grassy marshlands, where no surface indication hinted at their presence, is not one of the divining rod, but goes far into the realms of mathematics, physics, and astronomy. It involves the foundations of the science of applied geophysics.

Applied geophysics deals with the measurement of the various physical properties of the rocks of the earth, both on and below the surface, as these properties exhibit differences from place to place. Any means of detecting these minute differences in physical properties will tell something of the actual subsurface structure of the rocks themselves. It is the purpose of this article to describe the many ways in which scientific principles have been applied to this study of the physical properties of the surface of the earth. No attempt will be made to evaluate the various methods, but simply to describe the many ways in which the geophysicist has made use of old principles in this modern work.

The modern search for oil is based on the anticlinal theory, which states that if oil, gas, and water occur in bedded sands or sandstones, and the formation is uplifted into a closed upfold, anticline, or dome, as shown in figure 1, the oil, gas, and water will accumulate in distinct horizons in the sand body according to the specific gravity of each. This will tend to permit the oil to segregate itself into commercially recoverable quantities. The search for this type of formation was first carried on by the geologist

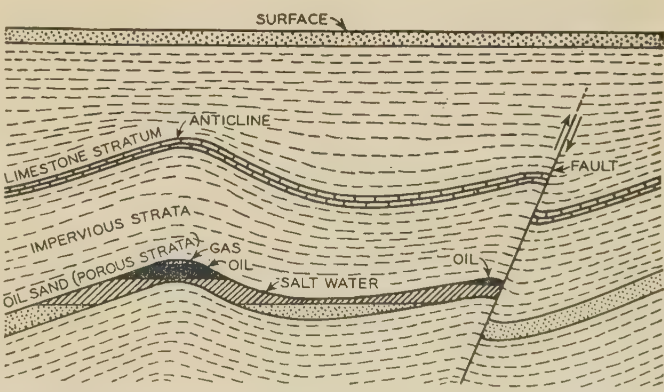


Figure 1. Diagram of typical geological structures, showing how oil and gas may be trapped

Essential substance of a lecture delivered at a meeting of the AIEE Tulsa Section, Tulsa, Okla., March 20, 1939.

DANIEL SILVERMAN is a geophysicist, Tulsa, Okla.

Figure 2. A magnetometer in field use

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on the basis of surface indication alone. However, it soon became evident that such formations could and did exist below the broad flat plains of the Gulf Coast region, and the use of methods that would probe below the surface became necessary.

The first attempt was to apply all known physical principles to the search. This naturally tended to the use of gravity forces, earth magnetism, electrical properties, seismic velocities, and radioactivity. These branches of physics are still the mainstay of geophysics, although some branches are less so than others. For gravity work the torsion balance, gravity meter, and the pendulum are used. In seismic work the refraction and reflection methods have shared the interest of the field. For magnetic measurements, the magnetometer, the magnetic variometer, and the earth inductor have been used. In the electrical field, resistivity measurements, transient-response measurements, the selective absorption and reflection of a-c fields, and radio waves, have been used for surface study, and resistivity and self-potential studies for well work.

Magnetic Methods

In applied geophysics, the use of magnetic principles is based upon the fact that different kinds of rocks, both on the surface and under the surface, will exhibit different magnetic properties, and thus create inequalities, or anomalies, in the normal earth's magnetic field. The measurement of these anomalies, and their interpretation, is the work of the magnetometer geophysicist.

Magnetic values appearing on maps showing oil or mineral prospects are given in units called gammas. This is a unit of field strength and is equal to 1/100,000 part of a gauss. For comparison, the normal vertical component of the earth's magnetic field is about 0.25 gauss. Lines connecting all points of the same gamma value are called isogams and appear much as structural or topographic contours. Thus a magnetic high will appear as so many gammas above normal, and a magnetic low as so many gammas below normal. These values are normally given for the vertical component of magnetic field intensity, because the interest of the geophysicist is generally applied to the magnetic properties of subsurface formations.

The group of instruments used for magnetic surveys, includes: the magnetometer and dip circle, which are used to measure the *direction* of the earth's magnetic field at any point; the vertical and horizontal variometers, which are used to measure the *change in magnetic field strength* from point to point; and the earth inductor, which gives a measure of the *total field strength*.

For use when the magnetic anomalies are small, such as those found over salt domes containing a small amount of disseminated magnetite or other magnetic ore, very sensitive and delicate types of variometers, similar to that shown in figure 2, have been developed which will read to one gamma. However, with such sensitivity, there are present many disturbing forces, for which accurate corrections are necessary. The general shifting of magnetic intensity over a period of years, the diurnal changes, the effects of temperature variations, and the changes due to magnetic storms, are the major sources of error.

In recent years, some basis has been found for changing the basic assumptions for the interpretation of magnetic anomalies. In former years it was thought that all magnetic anomalies were caused by a basement of shallow igneous or metamorphic rocks. Today it is believed that sufficient difference in the magnetic susceptibility exists in the sedimentary deposits to produce noticeable magnetic anomalies. Especially is this true in the Gulf Coast and in California where the basement is buried beneath a four- or six-mile-thick blanket of sediments. Since magnetic anomalies are observed, it stands to reason that they must originate with the shallower sediments.

Gravity Methods

The principle of operation of the gravimetric instruments is the universal law of gravitation which specifies that between any two masses there is a force of attraction dependent upon the product of their masses, and inversely proportional to the square of the distance between them. The value of these instruments in the search for oil is based upon the fact that the presence of oil is often associated with the presence of certain structures, some of which provide space-mass relationships that are susceptible of recognition by gravitational-force measuring instruments.

The two main types of gravimetric instruments, the gravimeter and the torsion balance, differ in their operation to the extent that the gravimeter measures the *force of gravity* at any point, while the torsion balance measures the horizontal *gradient of gravity;* that is, it measures the amount by which the force of gravity varies from one point to an adjacent point. Both of these instruments are affected by the gravitational force field, and are thus affected by near masses and those at a distance. By virtue of the inverse-square law, the distant ones are less effective, and there is thus a practical limit in the working depth of a gravity instrument. Furthermore, since all mass within the range of the instrument affects its indication, a given reading may be due to a small mass close to the surface, or to a large mass at some depth.

The gravimeter is sensitive only to the vertical component of gravitational force. Consequently it is not affected appreciably by surface structure. However, the torsion balance, since it measures horizontal change in the force of gravity, is sensitive to horizontal forces, and consequently is at a disadvantage where there are more major variations in level of the surface of the ground, even at considerable distances from the instrument.

The torsion balance, as its name implies, is an instrument in which the unbalance in two forces of attraction, for two ball masses suspended from a horizontal bar, is balanced by means of the torsion in a fiber by which the bar is hung. The two masses are horizontally displaced by equal amounts on opposite sides of the point of support of the fiber, and the horizontal elevation of one is less than the other by an amount roughly equal to their horizontal displacement. Thus, for masses below and to the side of the instrument, there is a difference in force on the two masses due to the different distances of the balls from the mass. It is this small differential force that is measured by the instrument.

Figure 3 shows a torsion balance in process of being set up at a station. A special type of housing is necessary to protect it from atmospheric or physical disturbances during the recording period.

The units of measurement used in applied gravity prospecting are the milligal and the eötvös. The milligal is the unit of measurement of the intensity of gravity represented by an acceleration of 1/1,000 centimeter per second per second, and is about equal to the one-millionth part of gravity at sea level. The eötvös is the unit of measurement of the gradient, or variation of gravity per centimeter, and is represented by 10^{-9} gals per centimeter (centimeters per second per second per centimeter). Since one gal is approximately 10^{-3} gravity, one eötvös is approximately represented by a change in gravity of one part in 10^{12} per horizontal centimeter of distance.

Figure 3. A torsion balance in carrying position

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The gravimeter and pendulum measure the vertical component of gravity. Since the period of oscillation of a pendulum is dependent upon the acceleration of gravity, the pendulum can be used as a gravimetric instrument. The field practice consists of the measurement of the variation in period of the pendulum as it is moved from point to point. These variations are observed by comparison with the period of a similar pendulum at a base station.

In the gravimeter, measurement is made of the change in position of a spring-supported mass under the effect of the gravitational field. The best gravimeters are sensitive to about one 10,000,000th part of gravity or less. This extreme sensitivity makes them responsive to small buoyant forces resulting from a change in barometric pressure acting on the mass, to small air currents caused by temperature changes, and to the change in spring constant of the suspensions with temperature. They are generally built in thermally insulated cases, with accurate thermostatic control of the temperature. Figure 4 shows one type of gravimeter for swamp work.

Core-Analysis Methods

Since the time when all surface indications of oil were investigated, and it was found necessary to go into the earth for information, one of the earliest and simplest methods was to drill. One step beyond the driller's log is the core log, and the record provided by the proper analysis of the cores recovered. Cores may be examined for water- and oil-bearing sands in strata too thin to register on the recording instruments of electrical devices.

The core drill uses a special type of bit that, while progressing down through the sediments, cuts away all but a small central cylinder which is left intact. This is carried in a central core cylinder or barrel, which is brought to the surface, and the core recovered. Core drills are of two main types: those that require removal of the drill stem from the hole, and the substitution of a core bit in place of a regular drill bit; and those of the so-called wire line type. These involve the use of a special bit and a core barrel which is introduced into the bit, and withdrawn from the bit, through the inside of the drill stem.

Core analysis is advanced to the point where it is an extremely important part of the total plan of prospecting. Chemical and physical analyses have been developed for the determination of the physical properties of the cores, and to indicate the value of porosity, the permeability of the sample to gases or liquids, and the percentage content of water and oil. These are extremely important to the oil operator. Additional information for the exploration department is available from further analysis of the core. This is in regard to the depth to certain strata, and the dips of the various planes of the strata composing the core. In other words, knowing the orientation of the core, and measuring the angle of inclination of the beds, the dip and strike of the various beds through which the well passes can be calculated. This information is extremely important in correlation work.

There are several different ways of obtaining this infor-

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Figure 4. A modern light-weight high-sensitivity gravimeter for swamp work

mation. One is to take a record of the orientation and inclination of the core barrel in the hole at the time that the core is being pulled. The other is a magnetic method of core analysis by which it is possible to measure the very small magnetic induction from the core itself, and align it with the known direction of the resultant earth magnetic field at the point. When these are aligned, the dip and strike of the beds can be determined. This magnetic effect depends upon the presence of minute quantities of magnetically susceptible material deposited in the sediments composing the stratum.

In a recently proposed method, the magnetic materials in the core are arbitrarily increased by injecting into the sediments at the base of the well, before the core is cut, a liquid jell containing minute magnetic particles. These particles are oriented in the earth's field and are bound in this position by the solidification of the jell. Upon cutting the core, a positive magnetization is observed, on the basis of which the core is oriented.

Soil-Gas-Analysis Methods

Ever since the day that the science of applied geophysics was first started, there has been a continual development of methods, and a continual search for new principles upon which to base investigations. One of these newer methods that has been under development for some time, in other countries perhaps more than in the United States, is the method involving the analysis of soil gas.

In the process of soil-gas analysis, there are several different methods of operation, some of which are based upon the presence of petroleum derivatives in the actual free gas withdrawn from the surface soil by means of vacuum pumps. Others make use of a study of the adsorbed gas in the soil at some small distance below the surface of the ground. Others are based upon the analysis for wax in the surface soil.

The basis of the claims of these methods is the theory that wherever there is a deposit of oil there is a seepage of hydrocarbon vapors upward through the various strata to the surface. There will be a certain minimum density of heavier hydrocarbons at all points, but the presence of more than usual amounts will be indicative of the deposit. Of course, where there is a weakening of the strata above the deposit, however slight, perhaps due to the intrusion of a salt plug or a fault, the seepage through these zones of weakness will be greater, and the larger amount of adsorbed hydrocarbons in the top layers of soil will indicate the fact.

Electrical Methods

The presence of oil in any deposit depends upon several factors, of which the two main ones are the presence of oil producing materials, and the proper structure or trap to catch and store the oil. Most geophysical methods can serve only to detect structure, which they do in different ways. Since all materials conduct electricity to a greater or less degree, these structures are susceptible to measurement by electrical methods. In order to find regions or deposits of good electrical conductivity, it is necessary to introduce currents artificially into the ground and trace their behavior. From the knowledge thus acquired, as to how the current distributes itself under the various arrangements by which it is introduced into the ground, the effects of local regions of good conductivity are noted and the presence of certain formations revealed.

There are several different methods of measuring the earth's resistivity, all of which are more or less similar in principle. They involve the introduction of current into the ground through two or more electrodes, and the measurement of the potential at two or more other electrodes. Their differences lie in the relative positions of the various electrodes, or the manner in which the voltages are applied, the type of current used, or the type of indicating meter.

The simplest and best known electrode arrangement is the Wenner configuration, which makes use of four electrodes, two current, and two potential. They are spread in a straight line, generally with equal intermediate spacing, with the two potential electrodes in the center. Applying a voltage to the two outer electrodes causes the current to spread throughout the whole volume of earth between these electrodes. By measuring the current and the potential, a value of resistivity can be computed which is the average resistivity of the region between the electrodes.

Many of the common operating difficulties in earth-resistivity measurement, such as polarization, leakage currents, and earth currents, can be eliminated by the simple expedient of reversing the current from the battery. The Gish-Rooney method is similar to the Wenner method, except that it provides switching, by means of a commutator, to reverse both the current leads, and the potential leads. In each reversal the potential leads are connected after, and broken before, the current leads. This cycle is repeated about 30 times per second. The apparatus is illustrated in figure 5.

A variation of the four-electrode Wenner configuration is the Lee partitioning spread, in which a fifth potential electrode is placed in the exact center of the configuration. In addition to providing resistivity measurements as before, this arrangement provides the additional information re-

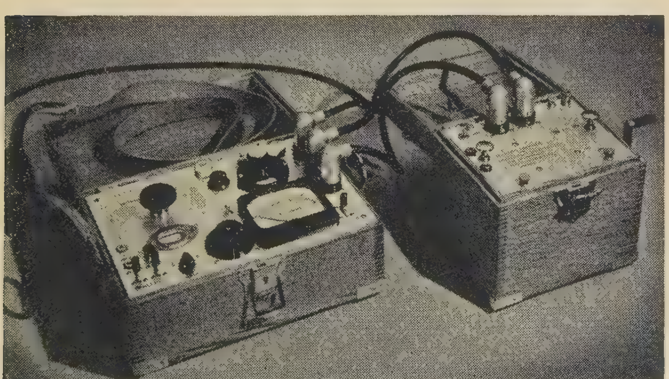
garding dissymmetry in the subsurface region under each half of the spread. This method is useful for the case where there is a dip of the beds, or where there are outcroppings or faults. For instance, if a fault line is crossed by the spread, and does not occur at the center of the spread, the side in which it does occur will show an average resistivity higher or lower than the other side, depending on the type of fault, and the nature of the fault zone.

Theoretically, the current that flows between the two electrodes fills entirely the underground space to an infinite extent. However, practically, the main part of the current flows in a region rather close to the surface, and the average resistivity measured corresponds to that at a depth of about one-third to one-fourth of the total current spread. This indicates that it is possible to change the depth of penetration of the current by merely altering the electrode spacing. This procedure of taking resistivity measurements by the Wenner method, with constantly increasing spacings is depth profiling. By this means, measurements to depths of several thousand feet are possible.

There are in general two methods of profiling by resistivity measurements. One is the depth profile just indicated, in which the electrode spacing is altered. The other is the constant-depth profile in which the electrode configuration is kept the same, but the entire spread is moved along the line of profile.

A recently devised variation of the steady-state measurements of resistivity is the electrical-transient method of prospecting. This involves electrode arrangements similar, in some respects, to those just described. Because of the large inductive effects between current and potential lines, the same linear arrangement of electrodes is used, but the potential electrodes are moved outside the space of the current electrodes.

By suddenly impressing a voltage between the current electrodes, a current builds up in the circuit in an approximately exponential manner depending upon the inductance and resistance in the circuit. At the same time a potential builds up between the potential electrodes, which more or less follows the shape of the current curve, but with much greater time constant. The exact form of the potential curve is not a true exponential, and it is the variation in this curve that is claimed to be indicative of the properties of the structure.



Geophysical Instrument Company

Figure 5. Gish-Rooney earth resistivity apparatus: left, measuring instrument assembly; right, commutator unit

In general this curve can be matched rather well by comparing it with the sum of two exponential curves of different amplitudes and time constants, and measurements are made on that basis. If a curve is plotted, with abscissas as distance along the line of profile, and ordinates some function of these amplitudes and time constants, then certain characteristic shapes of this curve are found, by trial, to be correlatable with the presence of faults, or other geoelectric anomalies.

Measurements are made in one of several ways. One is to take a picture of the transient by means of an oscilloscope and high-speed camera, and analyze the curve for its time constants. Another is to balance out the measured transient by another one artificially set up, and variable by means of changing resistances or capacitances. From the electrical constants of the dummy circuit, the time constant of the curve can be computed.

Well-Logging Methods

One important use of the electrical methods is in the electrical survey of wells. This was originally used as an addition to the driller's log and core log, for correlation purposes. However, by means of electrical measurements, additional information as to the porosity of sands and the presence of oil or salt water are indicated. Because of its value in the delineation of the boundaries of the various strata through which the bore hole passes, this method is extremely valuable in correlation work, and is, therefore, a useful tool for the geophysicist.

Electric coring is really an adaption of the circuits used for surface resistivity work, to measurement of the region surrounding the bore hole. One common circuit is the single probe configuration, in which two potential electrodes are maintained in fixed relation to, and above, one of the current electrodes, and the group of three raised and lowered together in the well. The second current electrode is at the surface of the ground.

By continuously recording the resistivity measured between the two potential electrodes, as a function of depth, a log of the well is obtained. With close spacing of electrodes, the penetration of the current is small, and the record represents the resistivity near the hole. With greater spacing, the penetration from the axis of the well is greater.

Alternating currents or commutated direct currents may be supplied to the current electrodes, and the corresponding potential measured at the probe electrodes. In addition to this derived potential, there is measured a spontaneous d-c potential which is generated in the drill hole. This may be due to the filtration of the mud filling the hole, into the formations, or to the contrast of the water filling the hole, to the fluid contained in the formation. The potentials measured are most intense opposite the permeable layers, so that the porosity log shows peaks opposite the sands, and flat curves opposite the impervious beds.

In practice, both the impressed and self-potentials are measured at the same time at the same electrodes, and a complete record of resistivity and porosity can be had in a single traverse of the well.

Thermal Logging

It has been found possible by means of a resistance thermometer, to take continuous measurements of temperature down a well. This record will provide further indication of the porosity of the beds, particularly when gas or liquid is issuing from any stratum. In the case of gas, the basis of this indication is that the expansion of the gas as it leaves the pores of the stratum and enters the well cools the surrounding space, and the difference in temperature is sufficient to be measured. The inflow of liquids from a porous stratum causes a change in the normal temperature gradient in the well, and thus the point of entrance can be detected. This method is also used for detecting points of water entrance into cased wells.

Gamma-Ray Logging

Because of the difficulty of applying the electrical logging methods in cased wells, it is necessary to look to other effects that are measurable. One such method that has been proposed involves the measurement of the radioactivity down the well. By using a modified Geiger counter circuit, and measuring the frequency at which the circuit is tripped by the radiation, a log of the gamma-ray emanations from each stratum is had.

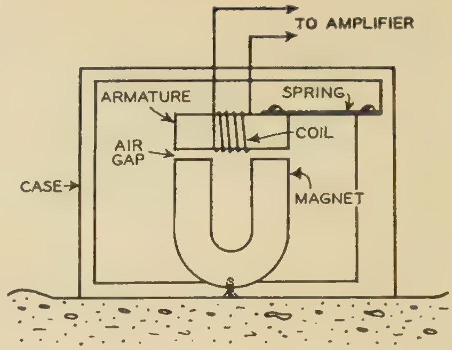
This log appears to correlate very closely with the electrical-porosity log (obtained before casing is set), indicating that porous sands show a minimum of radiation, and can be recognized by this effect. While not yet proved by actual use, this method shows considerable promise.

Seismic Method

Modern methods of petroleum production and oil-field development require a maximum of subsurface information in advance of drilling. In the search for new oil deposits, the more obvious structures have already been discovered and tested. New ones must be found by methods capable of interpreting the more complex subsurface conditions where surface geology affords little information. In many cases these structures will be deep seated, and will have little or no surface expression. Once found, structures must be tested by the drill before their potentialities as oil producers may be known, and since such drilling is costly, it is highly important that such subsurface information be as complete as possible from surface studies before any drilling is done. To this end, operators are utilizing the most advanced instruments in their search for oil. The most useful instrument, and at the present time, the most accurate one, is the reflection seismograph.

A seismograph is an instrument for recording the shock of earthquakes. In applied geophysics, the seismograph is an instrument for recording vibrations from the explosion of a small charge of dynamite buried in the ground. The responses of the seismographs are recorded photographically on records called seismograms. From the data on these seismograms, the time of travel of the seismic or elastic wave through the various rock strata can be determined, and much can be learned of the character and

Figure 6. Schematic diagram of a reluctance-type seismometer



structure of these subsurface beds, as well as the depth of the structure itself.

The earliest type of seismic equipment was the refraction seismograph, which provided an accurate measure of the velocity of seismic waves in the ground. Its value in the location of salt domes was great, because the materials of which the domes were composed had abnormally high elastic moduli. Large charges of dynamite were fired, and the arrival of the shock recorded on a number of seismographs set more or less fan shaped around the shot point. The times of arrival of the first waves were recorded and measured. This time, and the distance, usually of the order of several miles, gave a measure of the average velocity of the waves in the ground. If the line joining the shot point with any recorder coincided with the position of a salt dome, this time of travel would be abnormally short, and so would indicate a section of the earth in which the velocity of seismic waves was high.

As the number of undiscovered salt domes became less and less, and the number of new discoveries became fewer, the refraction seismograph became of less value. Because of the great attenuation of the waves refracted from great depth, enormous charges of dynamite had to be used in order to have a detectable received wave, which made operation expensive. However, it was not the cost of the method so much that caused its disfavor as it was the discovery that the *reflected* seismic waves from the explosion could be used to better advantage than the *refracted* waves.

In the reflection seismograph, the detectors, or seismometers, are vertical-component vibration detectors, and are sensitive to the waves that travel downward from the explosion and are reflected back from the surfaces of discontinuity between the subsurface strata. Knowing the time of travel of such a wave, and the average velocity over the path, the depth of the reflecting layer can be easily determined. It has been found that reflected waves will be returned to the surface from every plane or layer that represents a sharp difference in the elastic properties or density of the rocks above and below that particular plane or subsurface layer.

Reflection seismograph equipment is made up of seismometers, amplifiers, recorders, and miscellaneous equipment. The seismometers are used to pick up the seismic vibrations and convert them into electric currents, which are applied to amplifiers, and thence to a multitrace recorder. Individual seismometers, or groups in series, are applied to each channel of amplifier and recorder. While

theoretically it would be possible to make a depth determination by the use of only one seismometer, and one channel of amplifier, practically this is never done. One reason is that there are other types of waves that reach the seismometer before the reflected wave, and identification of the latter is difficult. Furthermore, by the use of two or more detectors, it is possible to determine not only the depth of the reflecting plane, but also its inclination.

Early seismic work failed to recognize this advantage. At that time the value of the additional detectors was mainly to be able to recognize the reflection. The seismometers being at different distances from the shot point, the direct waves would arrive at different times. But since the depth of the reflecting plane is large compared with the separation of the seismometers, the length of path for the reflected waves is almost equal, and they arrive at each seismometer simultaneously. This feature was evidence of the reflection. The interpretation of the operation of the seismograph in this way was the result of the first use of this instrument in locations where the dip was slight, and consequently the only quantity of interest was the depth. This use of the reflection seismograph was for the purpose of correlation. By determining the depth of a given bed (from which the reflection was recognized) at a number of points in a given territory, the contour of the surface can be plotted. This is still the main type of information derived from 50 to 75 per cent of the reflection-seismograph operations.

When the seismograph was used in locations of high-dipping beds, the fact that the reflections did not arrive at each seismometer at the same instant was evident, and its interpretation in terms of the dip of the reflecting plane discovered. This opened a whole new field of application, and today this instrument has considerable application in dip work.

The information read from the seismogram is the time of travel from the instant of shooting to the arrival of the reflected wave, and the "move out time," which is the difference in time of arrival of the reflection at the seismometers most widely separated. This information, with the horizontal spacing of the seismometers, serves to provide the value of depth and dip of the reflecting planes. When these are plotted, they provide a profile of the reflecting surfaces.

Theoretically, the maximum number of seismometers needed is the number that will provide an interval along the surface small enough so that the time of arrival of the reflected waves at adjacent seismometers will be within a few thousandths of a second. However, there are other advantages of additional seismometers, and the present trend is toward the use of more and more of them. From the point of view of signal-to-noise ratio, the more seismometers that are added in series, the less the relative amplitude of background or random vibrations. Furthermore, by proper placement of seismometers in series groups, they may be spaced so that the voltages induced as a result of the direct, or ground, wave will be out of phase in each one, and the sum of their output voltages will be zero. Practically this result is never quite reached, although there is an immense practical benefit in the reduction of random vibrations. For random waves, the improvement is proportional to the square root of the number of seismometers.

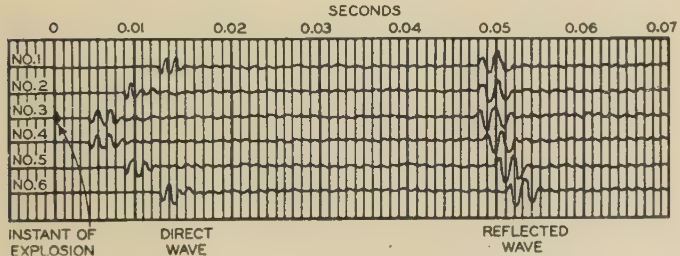


Figure 7. Idealized seismogram showing direct and reflected waves

Another feature that is often used to aid in correlating across the record is the use of groups of seismometers recording on two traces. This overlapping of seismometers tends to include portions of the energy on one trace in the energy of the adjacent traces. This makes it easier to recognize the reflection on all traces, and to correlate between the two seismometers that are to serve for the determination of move-out time.

Before the records can be interpreted, that is, before the depth and dip can be computed, the average velocity of travel for the reflected waves must be known. A general variation of velocity with depth can be postulated upon the increased density and elasticity of the deeper sediments. However, in each case, it is necessary actually to measure the velocity of the seismic waves. This is done by the use of a special type of seismometer, which is lowered into a well, and the travel time measured for waves initiated by a dynamite charge near the collar of the well. By measuring the time of travel of these waves for different depths of the seismometer, the curve of average velocity can be plotted as a function of depth.

Seismometers are vibration detectors, or electromechanical transducers. Most commonly used are the reluctance and dynamic types. However, seismometers utilizing carbon-microphone-button, piezoelectric, and magnetostrictive elements have been built and used. The greatest sensitivity and ruggedness are associated with the magnetic types. The construction, illustrated in figure 6, involves a spring-mounted mass of a certain period of oscillation which will best record the vibrations to be detected. The value of damping is generally quite critical, and various methods of obtaining the damping are used. Some are oil damped, others electromagnetically damped, and some even air damped. These units are extremely sensitive, and will record minute vibrations, of the order of ten 1,000,000ths of an inch in amplitude.

The amplifiers used are resistance-capacitance coupled, or transformer coupled. They are generally most sensitive in the range of from 30 to 100 cycles, and various systems of frequency discrimination are used. This is a matter of individual choice with the operators or observers. In some instances amplifiers are provided with several discriminations which are available at the turn of a switch, or by the change of a small filter unit.

Camera problems are similar to those in conventional

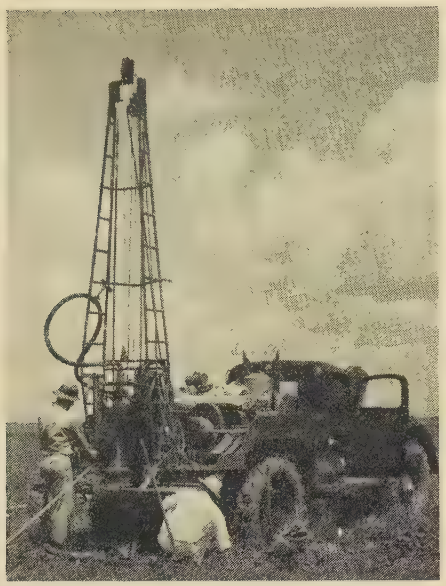
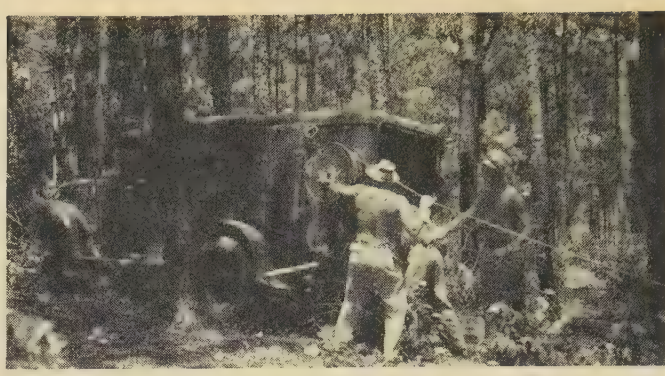


Figure 8 (left). Marsh-type drill

Figure 9. Recording truck operating in wooded area



oscillographs except that here the frequencies to be recorded are generally lower, and elements of greater sensitivity can be provided.

Timing problems are quite critical. It is necessary to be able to read time to 1/1,000 second, and consequently is necessary to have a very accurate time source. There are several systems for timing records. One involves the use of a temperature-corrected tuning fork driving microphone buttons to provide a 100-cycle source of voltage. This drives a small synchronous motor with a time wheel that periodically interrupts the light from the exciting lamp, thus providing a line shadow across the record. Another system makes use of a tuned reed that is set into vibration at the instant of firing of the charge, and which interrupts the light beam periodically. Another system makes use of a vacuum-tube-driven fork and timing motor. In each system, the records are marked by time lines across the sheet, each 1/100 second apart. The records are then estimated to 1/10 division, or to 1,000ths of a second. Reading time to 1/1,000 second provides depth information to the order of about five feet. (See figure 7.)

The exact time of explosion must be determined very accurately so that the travel time can be measured. One method is to wrap the dynamite with a small copper wire through which a current is passed. This current is cut off by the breaking of the wire at the instant of the explosion, and the record shows this time. Another method involves recording the instant at which a small metal fuse ruptures in the cap that detonates the dynamite. In this case the current from a blaster is passed through the fuse, and its heating detonates the charge. The rupture of the circuit takes place as a result of the detonation.

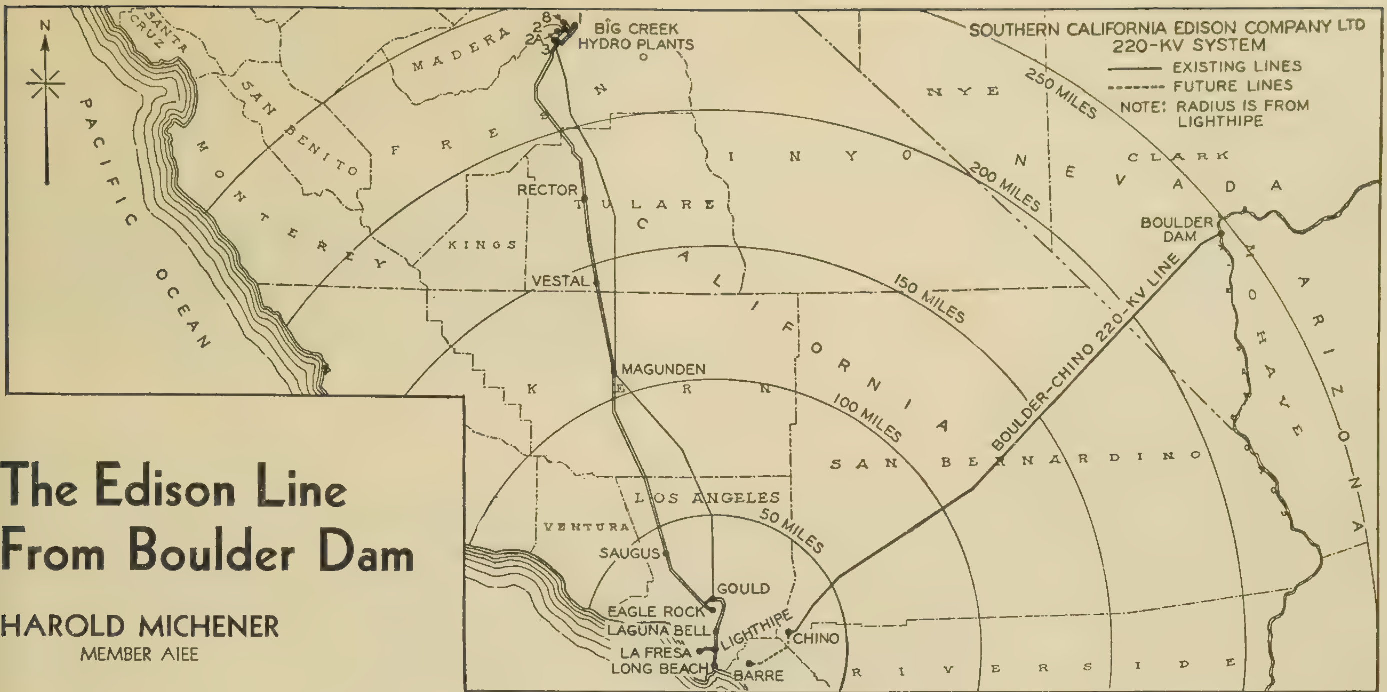
In addition to these major problems, there are the problems of photography involved in the developing of the records, telephone or radio communication to and from the shot point, and the construction, care, and handling of cables. This is quite important, particularly for some of the longer spreads.

The most important part of the recording of reflections is the matter of volume control. Since the seismometers are in general quite close to the shot point, the incident energy immediately after the first arrivals is enormously greater than that after some time has elapsed. In other words, in order to hold the record to uniform amplitude, it is necessary to provide some sort of control in which the beginning of the record can be attenuated in a ratio of some 2,000 to 1. Early equipment made use of fixed steps of attenuation. Since it was obviously impossible to choose the exact instant when the switch should be thrown from one step to the next, only small portions of the records were of proper amplitude, and so shots had to be repeated in order to be able to get all portions of the record at proper amplitude.

Later equipment made use of fixed-rate gain controls, in which the attenuation started at a very high value and was gradually reduced with time according to a fixed exponential rate set by the discharge of a condenser. By choosing the proper rate, a record of more or less uniform amplitude could be obtained. Later methods involve the use of automatic volume control of the radio type to provide a record of constant amplitude throughout its length. The matter of proper volume control is extremely important as the number of strings increases, in order to avoid having strings tangle (in the case of the string camera) and in order to make the record more readable.

The actual instruments used for the recording of the travel-time data are only a small part of the entire seismic equipment. The full equipment consists of a rotary drill used for drilling the shot holes, which may vary from very shallow holes to holes up to some 500 feet in depth, a water truck which carries drill pipe and water for drilling, a shooting truck which carries the dynamite and water to tamp the charge, and the recording truck. In addition, there is equipment for the permit man and surveyors. The drilling and recording operations are illustrated in figures 8 and 9.

The operating difficulties in the field are often quite serious. This is particularly true in wet weather, or in swampy territory. All these truck equipments are heavy, in spite of attempts to reduce the weight of all items. In bad territory, oversize tires are commonly used, which permits operating in even the worst weather. In any case winches are provided so that when trucks become mired they may have some help in getting out. In real marsh country even these trucks are helpless, and it is necessary to go to an entirely different type of vehicle in which the wheels are huge air drums able to float the truck in water.



The Edison Line From Boulder Dam

HAROLD MICHENER
MEMBER AIEE

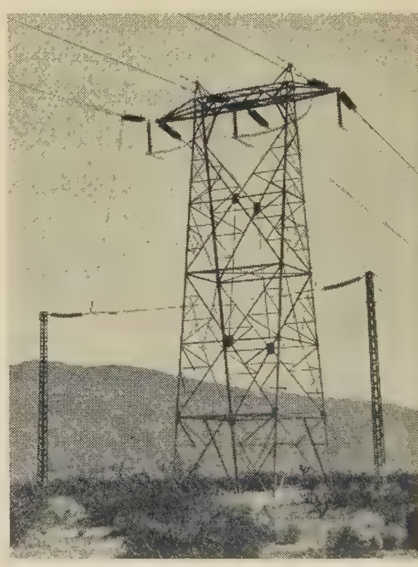
To transmit its allotment of power from Boulder Dam to its system, the Southern California Edison Company, Ltd., has completed and recently placed in operation a 233-mile, single-circuit, 220-kv line of simple and time-tested design, the principal features of which are here outlined.

SHORTLY after the passage of the Federal Water Power Act in 1920, the Southern California Edison Company, Ltd., began a study of the possibilities of power development on the Colorado River. Topographic surveys were made, in collaboration with the United States Geological Survey; a river-gauging station installed at Lee's Ferry, Ariz.; and core drillings made at the Glen Canyon and Callville dam sites. Having completed a comprehensive plan for power development between Glen Canyon and Topock, the company filed application for license with the Federal Power Commission. The application was pending when Congress passed the Boulder Canyon Project Act, December 21, 1928, and subsequently was refused.

According to the terms of the Act, the power was allotted by contract before construction of Boulder Dam was begun, to several distributing agencies including the Edison company. Co-operating with the United States Bureau of Reclamation and other agencies on plans for the equipment of the powerhouse, the company arranged that a unit system—one generating unit to a bank of transformers—should be provided for the four 82,500-kw units tentatively allotted to its use. This plan eliminated the low-voltage generator switches for these units, and the Arizona side of the powerhouse was designed and built accordingly.

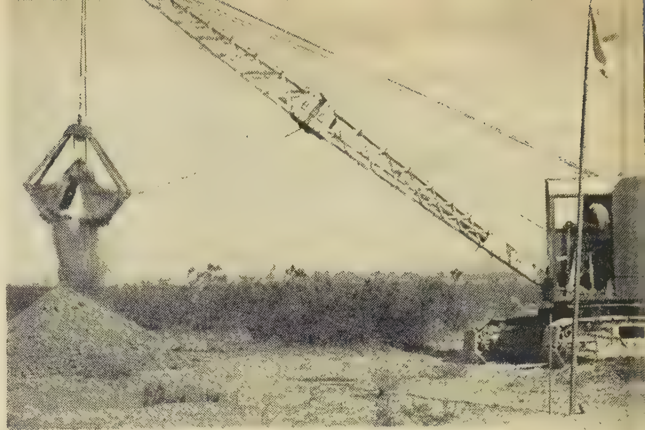
Study of transmission facilities indicated that a single-circuit 220-kv line, similar in construction to those long in operation on the Edison system and capable of delivering 150,000 kw, would be most economical for the delivery of power from the first two generating units to be installed for the company. Construction of two lines with cross-over switching stations was considered unnecessary, since the powerhouse is but one of three major sources of the company's power.

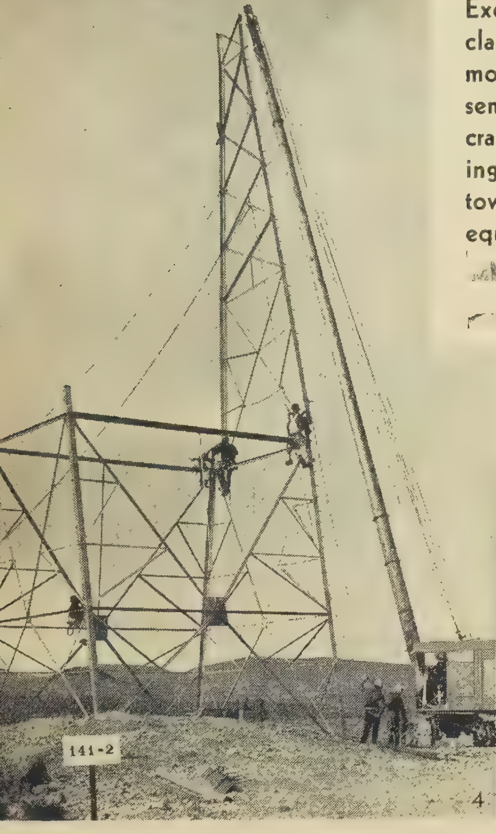
Chino substation, an existing 66-kv and 11-kv substation, at Chino, San Bernardino County, Calif., and Barre substation, now under construction near Stanton, Orange County, Calif., were chosen as receiving stations for the first line. Each has a 75,000-kva 220/66-kv transformer bank and a 50,000-kva synchronous condenser. Construction of the line originally was planned for completion by the summer of 1938, since the power would have been required if dry weather had affected the company's major water power plants on the upper San Joaquin River. However, since an unusual abundance of water was available in that drainage area in the spring of 1938, construction of the line was retarded. The first Edi-

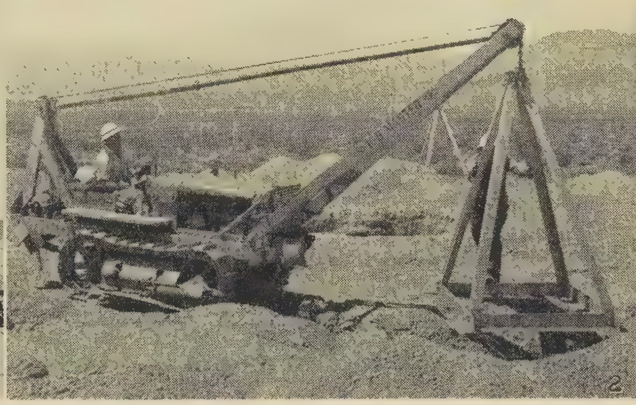


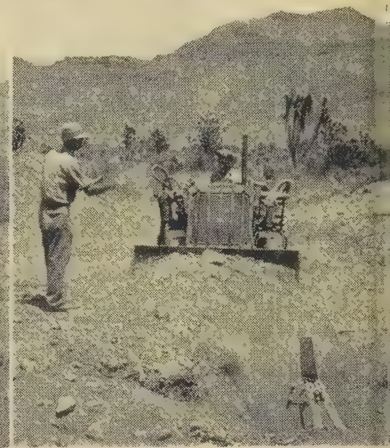
Transposition on a dead-end tower; the only type of transposition used on the line

HAROLD MICHENER is transmission engineer for the Southern California Edison Company, Ltd., Los Angeles, Calif.









Excavating for tower footings with clamshell bucket and tractor-mounted crane (1); placing assembled footing with small tractor crane (2); backfilling around footing with bulldozer (3); erecting tower with tractor-mounted crane equipped with long wooden boom (4)

son company unit at Boulder Dam began delivering power over the line in July 1939, according to the revised schedule.

Protection for the Line

Since most of the short circuits experienced by this company on its 220-kv lines during 15 years of operation have occurred between one conductor and ground, and since this line would be isolated from other 220-kv lines, it was decided to install ground-fault neutralizers (Petersen coils) in connection with the banks of transformers on both ends of the line.

In addition to the ground-fault neutralizers, which are expected to prevent interruptions to service on this line whenever one conductor becomes temporarily grounded, the line is protected by four-element instantaneous overcurrent relays, one element being used for residual currents when phase-to-ground faults occur at times when ground-current neutralizers are short-circuited, in which cases the circuit breakers at each end of the line open simultaneously for faults near the center of the line, and in sequence for faults near the ends of the line. The other three elements of each are used for phase currents to open the line at one end in cases of phase-to-phase faults near that end of the line. To open the other end of the line in such cases, and to clear the line when a phase-to-phase fault occurs near the center of the line, it is necessary to use at each end of the line three double-element balanced-current relays. These are adjusted so that if the phase current in one element is ten per cent greater than that in the other element, the tripping contacts will close.

No sectionalizing switches have been installed in this line, it being planned that means will be provided for determining the location of a permanent ground fault on a conductor without sectionalizing the line.

Description of Boulder-Chino Line

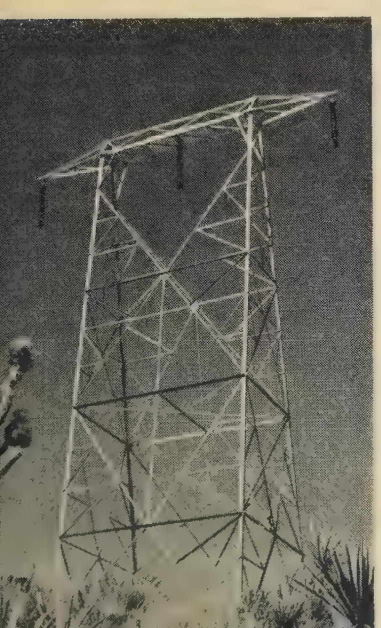
The route of this 233.3-mile line is closely defined by Boulder City, the stations of Nipton, Cima, and Sands on the Union Pacific Railroad, Pisgah on the Santa Fé Railroad, Lucerne Valley, Cajon on the Santa Fé Railroad, and the city of Chino. This route was chosen, after careful investigation of other possible routes, on the basis of lesser estimated cost, avoidance of bad ice-loading conditions in the San Bernardino Mountains, avoidance of interference with communication lines, and as great a distance as feasible from other transmission lines delivering power from Boulder to the southern California area. Certain disadvantages were recognized as inherent in some sections of this route, such as the difficulty of making and maintaining a road through the blow-sand of the Devil's Playground, in the vicinity of Sands, and the footing difficulty in the Lucerne dry lake. However, this route seemed to have a lesser aggregate of evils than any one of the other routes considered.

The region traversed by the route selected is mostly arid desert land from Boulder to the southern edge of the San Bernardino Mountains, a distance of 212 miles. In this section, about 65 per cent of the lands crossed are owned by the Government, either Federal or State; land values are low and the necessary ties to existing surveys few; temperature ranges are great, from 0 to 135 degrees Fahrenheit; high winds, which fill the air with sand, are

Type of Construction, Boulder-Chino 220-Kv Transmission Line

Spans	Minimum, 288 feet; maximum, 3,128 feet; average, 1,398 feet.
Towers	
Type	Wedge type so commonly used for high-voltage single-circuit transmission lines.
Number	Total 880, or an average of 3.77 per mile; 67 anchor, 813 suspension.
Height to Crossarm	Seventy-foot anchor, 78-foot suspension, with standard legs; or provided with 3 feet shorter, 6 feet shorter, 3 feet longer, 6 feet longer legs; or with extensions 6, 12, 18, or 24 feet in height.
Weights Without Footings	Type *L*, 9,171 pounds; type *H*, 10,960 pounds; type *S*, 13,788 pounds; type *D*, 14,994 pounds.
Footings	Normally pyramid-type steel footings. Plates or stanchions added where greater bearing area required due to sand. Concrete footings in and near dry lakes, both where bearing value of soil is poor and where corrosivity of soil is great.
Conductors	Steel-reinforced aluminum cables, 605,000 circular mill, 0.994-inch diameter, 30/19 strand. Horizontal configuration, 23 feet separation. Ultimate strength 30,000 pounds. Maximum design tensions 14,000 and 10,000 pounds, under heavy and light loading conditions respectively.
Overhead Ground Wires	Two one-half-inch, seven-strand, zinc-coated, extra-high-strength steel, located approximately midway between and 12 feet above the conductors at the towers. Ultimate strength 26,900 pounds. Maximum design tensions 11,000 and 8,400 pounds under heavy and light loading conditions respectively.
Counterpoises	Two radial counterpoises per tower where footing resistance was near or greater than 100 ohms. Each counterpoise consisted of four one-half-inch, seven-strand, galvanized-steel cables, 200 feet long, buried from $1^1/_2$ to 2 feet deep in the same trench. Average tower footing resistance after installation of counterpoises, 9.3 ohms for the 54 towers where counterpoises were installed.
Insulators	Ten-inch diameter, $5^3/_4$-inch spacing, heavy section, cap and pin, ball-and-socket connection, suspension insulators. 15 units in suspension strings and two strings of 16 units each in dead ends. 25,000-pound units in dead ends and peak suspension positions in heavy loading districts; otherwise 15,000-pound units in both dead-end and suspension assemblies.
Hardware	Mostly forged steel of standard commercial lines with modifications to fit requirements. Arcing horns at suspension clamps and at both dead-end yokes, but no insulator grading ring. Aluminum Company of America design of conductor splices and compression dead ends. Nicopress steel splicing sleeves for ground wires. Bolted cast-steel clamps for ground-wire dead ends. Bolted cast-iron clamps for attaching ground wires rigidly to suspension towers, except where line angle is greater than three degrees, in which cases ground wires dead-ended. Stockbridge vibration dampers on both the conductors and ground wires.
Bird Guards	Saw tooth on outer six feet of crossarms; pans on center eight feet, with pan extensions on inner end at angle towers.
Communication	Two-wire telephone line roughly paralleling the transmission line, and most of the way in combination with existing communication circuits. Also, carrier-current telephone on transmission line.

frequent; existing accommodations for construction crews are few and far between, and suitable locations for camps away from these existing accommodations are nonexistent. For these reasons, methods of survey and construction were used which would require a minimum number of men to complete the line within the desired time limit. The stadia method of survey and the use of adequate power equipment for road building and line construction were the principal means to this end. The illustrations on page 464 show some of the equipment used, and completed towers are shown on this page and page 463.



Completed suspension tower (type H)

The construction work was begun in November 1936 and carried on by the Southern California Edison Company, Ltd., until June 1, 1937, during which time a large portion of the road was built and a small portion of the footings was set. On June 1, 1937, Stone and Webster Engineering Corporation took over the construction of the line. The survey work, the acquisition of right of way, and the office engineering remained in the hands of the Edison organization. The type of construction used for the line is indicated in the tabulation.

The operating record of the Boulder-Chino line will be watched with interest, chiefly because of the use of ground-fault neutralizers and because of the high load imposed upon the line.

Lightning Strokes in Field and Laboratory

P. L. BELLASCHI
MEMBER AIEE

Recent developments in the lightning-stroke generator have made substantial contributions to lightning research

SINCE the time that currents of lightning-stroke intensity were produced in the laboratory,[1] lightning generators have been the object of continual development and of extensive application.[2,3] This article refers briefly to the developments of the lightning-stroke generator in recent years and also to substantial contributions to lightning research that the new forms of generator have made possible.

The arrangement in figure 1 consisting of the high-voltage generator (*A*), the high-current generator (*B*), and the microsecond switch (*C*) has been used for several years. For engineering purposes and research where the voltage and the high current of the stroke (figure 2) are the two elements of importance, this arrangement of the lightning-stroke generator is the one to use.

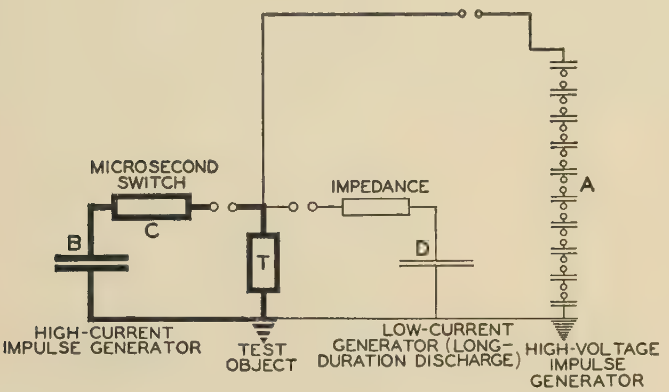


Figure 1. Schematic diagram of lightning-stroke generator

Visual observations of lightning have indicated the occurrence of prolonged discharges estimated to be in the order of a fraction of a second or more. The presence in lightning strokes of long-duration low-current components following the initial high-current discharge has been well established photographically by B. F. J. Schonland and his associates. The phenomena of the stroke discharge that give rise to the sustained components have been analyzed in considerable detail by them.[4] Fulgurites,[5] heavy fusion of metal objects, fires, and similar effects have likewise established the presence of sustained low-current components in lightning strokes.

One form of the lightning-stroke generator that has been devised to produce the combined voltage and current components (figure 2) of the lightning stroke is shown schematically in figure 1. Considerable laboratory research with this and similar arrangements and correlation of extensive test results on long-duration components with corresponding field data and records have established that:

> "The effective current of long-duration components of lightning strokes may range from a few hundred to several thousand amperes. The corresponding durations apparently range from 0.1 second, and even longer in some cases, to about 0.001 second."

It is of interest to note that the high-current components and the long-duration components of low current in lightning strokes have recently been recorded by the oscillograph in field investigations in Europe[6] and in the United States.[7]

Some of the results from tests conducted with various forms of the lightning-stroke generator are summarized in tables I and II. From these and from other findings it is clearly apparent that shattering, bursting, explosive effects, and similar damage to objects hit by lightning are caused largely by the high-current short-duration discharge of the stroke,[8] whereas, fires, heavy fusion of metal, fulgurites, extensive burning, and other similar effects result largely from the relatively low-current components in the stroke discharge that may be sustained even for a substantial fraction of a second.

Figure 3 shows a stack of excelsior which was ignited instantly on discharging through it a long-duration current from the lightning-stroke generator (see table I for current duration). The fulgurites in figure 4 were produced by similar long-duration discharges through sand. These were observed very shortly after the sand was fused

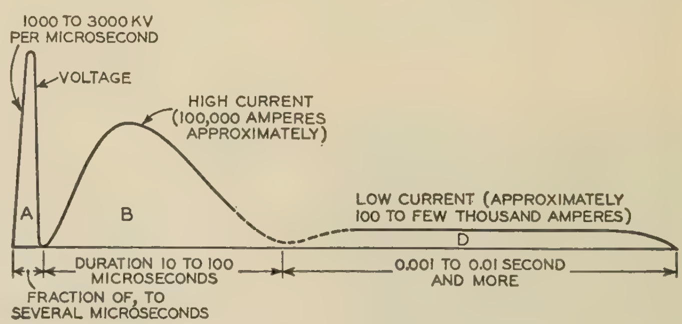


Figure 2. Schematic representation of lightning-stroke discharge

and to all appearances the fulgurites formed constituted a glowing, intensely white-hot mass.

The relative loudness of the discharge for high currents of short duration and for low currents of long duration

P. L. Bellaschi is section engineer, transformer engineering department, Westinghouse Electric and Manufacturing Company, Sharon, Pa.

Table I. Resultant Condition of Various Test Specimens When Subjected to Measured Current Discharges of Long and Short Duration

Test Specimen	Surge Current* Crest Value (Amperes)	Surge Current* Total Duration (Second)	Effects
Discharge through fine carborundum	4,700	0.028	Fulgurites produced. External diameter approximately 8 millimeters; internal diameter approximately 3 millimeters.
Discharge through sand contained in fiber tube	17,000	0.0045	Fulgurites produced. External diameter approximately 13 millimeters. The fulgurites were observed at the instant produced. They were then of white incandescence (fused sand) and externally they appeared in a substantially solid state.
Discharge through sand	100,000	0.0004	Sand scattered by blast action of discharge. Test repeated with similar results.
Discharge through clean cotton cloth	4,700	0.028	Cloth ignited. Test repeated with similar results.
	17,000	0.0045	Cloth ignited. Test repeated with similar results.
	100,000	0.0004	Cloth scorched and torn but *not* ignited. Three holes 15 to 30 centimeters torn in cloth. Specimen blown off by blast action of discharge. Test repeated with similar results.
Discharge through excelsior	4,700	0.028	Excelsior instantly ignited.
	100,000	0.0004	Excelsior scattered through laboratory but *not* ignited.
	100,000	0.0004	Excelsior more loosely packed than in the preceding test. Excelsior somewhat scattered; the part left on test stand ignited and gradually set into flames.
Discharge through paper (white paper used in drafting)	2,000	0.0023	Paper ignited.
Discharge through paper (white, brown express, etc.), through cloth, etc.	100,000	0.0004	Numerous tests made on paper, cloth, etc. In no instance was material ignited. Some scorching was the only effect observed.
Lightning-stroke test of distribution wood poles. Approximately 60 poles tested. Occasionally tests were repeated after shattering and splintering the pole. Some of the poles were dry, others wet	50,000	0.0001	Of approximately 60 poles tested, in only one instance was the wood of the pole ignited. In this particular case the pole had already been tested two or three times and was well splintered and broken. Moreover, the wood of this pole was well dried.

* Surge current recorded with the cathode-ray oscillograph.

Table II. Relative Loudness of Measured Current Discharges of Long and Short Duration in Air

Surge Current Crest Value (Amperes)	Surge Current Total Duration* (Second)	Relative Loudness of Noise
100,000	0.0004	Unbearably loud; painful to ear.
17,000	0.0045	Painful effect substantially reduced.
4,700	0.028	Noise fully bearable and similar to removal of cork from bottle.
2,000	0.0023	Noise inaudible unless person stood in laboratory.
850	0.0023	

* Duration to crest (front) is proportionately greater for the respective discharges from the top to bottom of the tabulation.

Figure 3. Excelsior ignited instantly when a long-duration current from the lightning-stroke generator was discharged through it

are compared in table II. As previously established, the thunder following the lightning flash results from the explosive expansion of the channel and is due to the high-current initial discharge. Strokes to or from elevated objects, between clouds, and under special conditions have been observed in which the current is largely a long-

Figure 4. Fulgurites produced by passing long-duration discharges from the lightning generator through sand

duration component.[7,9] Such discharges naturally are not accompanied by appreciable noise.

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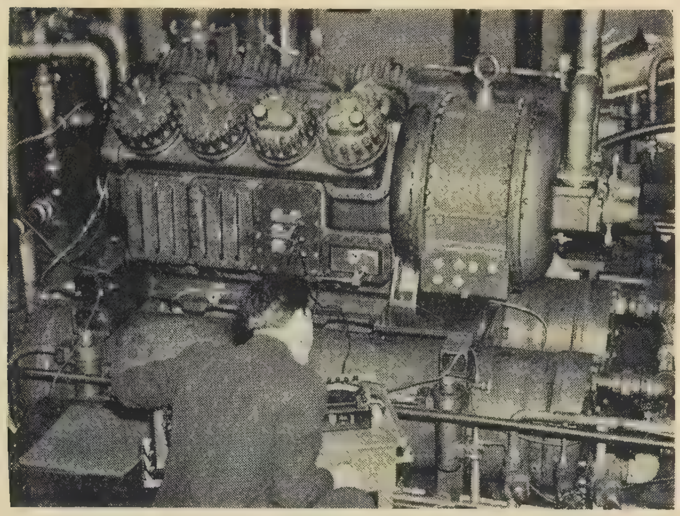
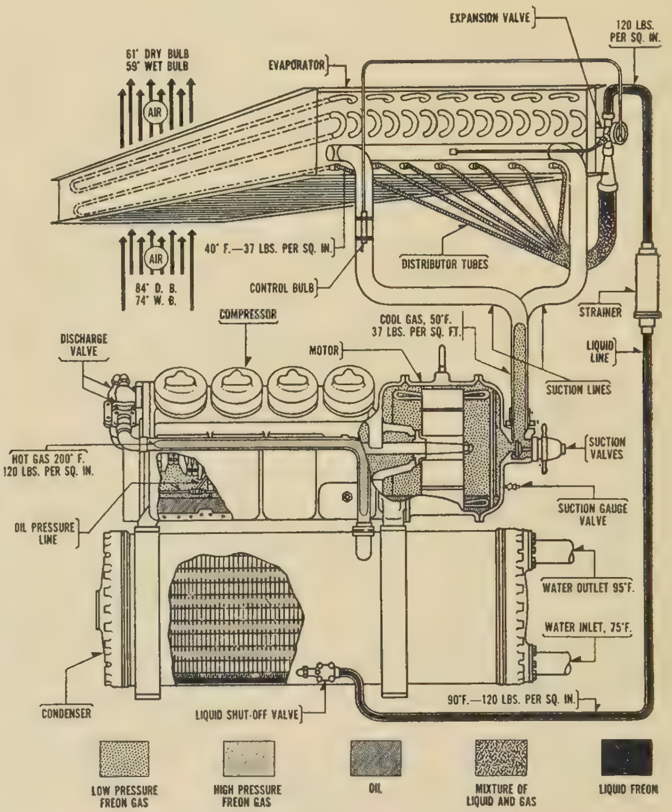
Refrigerant-Cooled Motor Drives 100-Ton Compressor

COMPLETION of a hermetically sealed 100-ton 16-cylinder air-conditioning compressor unit driven by a 100-horsepower 1,150-rpm refrigerant-cooled motor recently was announced by the air-conditioning department of the Westinghouse Electric and Manufacturing Company, East Springfield, Mass. The new unit is intended particularly for stores, factories, theaters, and similar applications. Of extremely compact design the unit is said to require only one-third the space that would be required by a compressor of conventional design for the same capacity, and to weigh only two-thirds as much. It weighs 4,200 pounds and its over-all dimensions are: length 90 inches, width 34 inches, and height 36 inches. The single-unit type of construction permits of sealed-in lubrication, and a reversible oil pump prevents harm when motor phase connections are inadvertently reversed, thereby reversing the direction of rotation. The refrigerant is Freon.



Compressor unit undergoing test

A typical operating cycle for the new compressor unit is shown in the accompanying diagram, as well as the general design of the unit itself. From the suction manifold of the evaporator the relatively cold refrigerant gas sweeps through the windings of the driving motor. After cooling the motor, the low-pressure gas enters a manifold, then through the intake feather valves, into the cylinder where it is compressed and expelled through separate feather-valve ports into the high-pressure discharge line. The high-pressure gas passes down into the condenser where it is condensed by contact with the water-cooled tubes. Liquid refrigerant enters the liquid line from the bottom of the condenser, passes through a strainer, and enters the expansion valve. The liquid begins to expand into a gas as it passes through the expansion valve and distributor tubes, and continues to expand during its course through the evaporator. In this process, the air passing over the evaporator fins is cooled, as a portion of its heat is absorbed through the evaporator tubing walls by the boiling refrigerant inside. The refrigerant is completely vaporized by the time it reaches the valve control bulb, and enters the suction line as a low-pressure gas to complete the cycle. Temperatures and pressures shown are not exact but merely indicative of general conditions in a typical cycle.



Typical cycle of operation

Vertical-Shaft Generators—

Some Problems and Their Solutions

A review of some of the problems involved in the design and construction of vertical water-wheel generators, and methods of solution

H. R. SILLS
MEMBER AIEE

THE DESIGN of electrical apparatus "involves the correlation of three distinct kinds of engineering: electrical, mechanical, and thermal. In general, no one of these three aspects of design can be given first place in importance, although in particular cases the application and duty of the apparatus may determine one or another aspect as the limiting feature.

"In designing a new machine, an engineer has therefore to visualize not the physical appearance of the machine but rather its three interrelated circuits—the electrical, mechanical, and thermal. By shifting his point of view he can bring any one circuit into the foreground, just as in staring at a certain kind of optical illusion one sees first one figure, then another, although the actual lines in view remain unchanged. To design any one of these circuits is a comparatively simple matter; it is the co-ordination of the three circuits to best advantage which is the real engineering problem. Like in the optical illusion in which it is easy to see any one figure at a time, but extremely difficult to see all figures at the same time, it is correspondingly difficult in design to visualize all three circuits simultaneously. But difficult or not, the designer must keep all of them and their usually conflicting requirements in view continuously."*

This introduction, quoted from a paper by C. Concordia,* admirably defines the fundamental problem back of the design of vertical-shaft generators. It would be a fairly straightforward matter to talk of the electrical, mechanical, or thermal problems of generator design were each of these not influenced so greatly by limitations introduced by the other two. A quite satisfactory electrical design could be laid out that would be utterly impracticable because it might neither hold together nor dissipate the heat generated by its losses.

It must be borne in mind that a vertical-shaft generator is tailor-made equipment, designed to suit particular requirements in the same manner as a bridge is designed; and, like a bridge, it is first built on paper on the basis of fundamental theory and practical experience.

Energy in a Hydroelectric System

The first law of thermodynamics states that the energy in an isolated system remains constant and cannot be increased or diminished by any physical process whatever. The second law is that of the degradation of energy, according to which the result of any transformation of

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H. R. SILLS is assistant engineer, a-c and d-c engineering department, Canadian General Electric Company, Ltd., Peterboro, Ontario, Canada.

* SOME REMARKS ON DESIGN ENGINEERING, C. Concordia, *General Electric Review* July 1936, page 317.

energy is a reduction in the quantity of energy available for useful work.

By considering all types of energy as a single concept, irrespective of whether it is hydraulic, mechanical, electrical, magnetic, or thermal, it is possible to sketch a flow chart of energy from the penstock of a hydroelectric plant to the transmission line as shown in figure 1. A diagram of this type gives a useful composite view of where the energy goes, the relative amount of the losses and the size of the reservoirs of potential energy. It may be seen that in the mechanical system sufficient potential energy is stored in the flywheel to supply or absorb full power flow for between two and five seconds. The whole of this potential energy cannot be used, as it would mean bringing the machine to a standstill; but for known load changes and governor response, it is possible to determine the frequency change. Likewise, in the excitation circuit there is a supply of potential magnetic energy that is drawn on to supply excitation for momentary or transient loads until the regulator can adjust the excitation to suit the load. In the thermal circuits, there are considerable reservoirs of sensible heat in the mass of copper and iron of rotor and stator that can absorb considerable momentary increases in losses without a proportionate increase in temperatures. These values can all be expressed in time, as the dimensional formula for power and heat flow is L^2MT^{-3} and for energy and heat L^2MT^{-2} (where L represents length, M mass, and T time); consequently the ratio is expressed in time.

This concept of total energy flow is the same for horizontal as for vertical machines. The design of the electric circuit is the same irrespective of whether the machine has a horizontal or vertical shaft. The fundamental difference between a horizontal-shaft generator and a vertical-shaft generator is that in the former gravity acts perpendicular to the shaft, and in the latter parallel to the shaft. Mechanically this is a large difference.

Weight and Its Support in a Vertical Generator

Vertical-shaft generators are massive pieces of equipment, and the forces due to gravity alone are large. The average generator of more than 5,000 kilovolt-ampere will weigh between 2,000 and 3,000 pounds per kilovolt-ampere per revolution per minute. Of this weight about 26 per cent is in the stator, 55 per cent in the rotor, 5 per cent in the base, and the other 14 per cent in the supporting brackets and miscellaneous parts.

The first thing the machine must do is support its own weight both when assembled and as individual parts during fabrication and shipping. Figure 2 shows these forces. Sketch A indicates the weight of the individual parts as a factor of the total weight; B shows the distribution of weight when the rotor is suspended from a thrust bearing on the upper bracket; C the distribution when the weight is supported on the lower bracket. In addition to the weight of its own parts, the shaft supports the weight of the water-wheel runner and shaft shown in D and the reaction of the thrust of the column

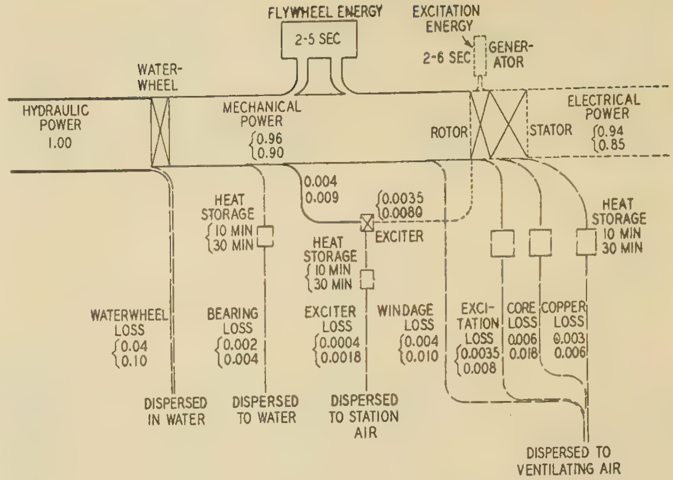


Figure 1. Flow chart of energy in a hydroelectric system

of water turning the wheel as in E. The weight of waterwheel runner and shaft and the water thrust is from 50 to 70 per cent of the weight of the unit for a Francis-type wheel, and from 150 to 200 per cent for a propeller-type wheel. It is this proportionately large thrust load that is the outstanding feature of vertical-shaft generators, and probably the most important single point in determining the general mechanical construction.

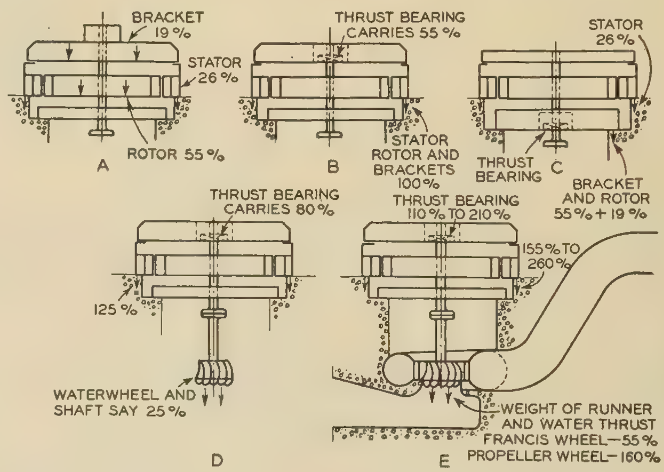


Figure 2. Distribution of weight in a vertical-shaft waterwheel generator

Several types of thrust bearings have been developed that are capable of carrying these large thrust loads (up to 3,000,000 pounds) reliably. Such bearings in the large sizes are of the spring-supported or pivoted-shoe type. In the smaller machines thrust bearings of the antifriction type sometimes are used. The bearing introduces no particular problem in itself, but the question of where it is to be placed, and how it is to be supported is a problem. Of the many aspects of this problem, some are inherent in the generator, but most of them are dependent upon requirements of the water wheel and the power-hourse design.

The water-wheel builders want a stiff bracket support

to be able to use small clearances in their wheels. It seems to be more or less agreed that a vertical deflection of $^1/_{32}$ inch from no load to full load is satisfactory for a Francis-type runner and $^1/_{16}$ inch for a propeller type. The water thrust (the only variable part of the thrust load) is about 33 per cent of the thrust-bearing load with a Francis wheel, and 66 per cent with a propeller-type wheel, so a total deflection at maximum load of approximately $^3/_{32}$ inch seems reasonable. From the point of view of the generator this amount of flexibility of the bracket is highly desirable, because excessive stiffness can only be secured by great depth in the bracket, which throws the proportions of the bracket out of line, increases the weight and cost, takes up valuable space, and makes the reaction on the bracket supports difficult to equalize, causing uneven distribution of the stresses.

In further explanation of the foregoing point, the thickness of the oil film that carries the load is about 0.001 inch and the thrust bearing may be from 80 to 100 inches in diameter; this requires that a level of 1 in 100,000 be maintained under all conditions of load in order to have equal distribution of the load over the bearing surface. No foundation will maintain such a precise level, and no bracket will not warp more than this amount from temperature changes. Obviously then, the alignment of the rotating and stationary parts of a thrust bearing must be obtained either by flexure of the bracket, the shaft, or bearing springs (in the spring-type bearing).

Figure 3 shows a representative thrust block and retaining ring. It is in the shaft back of the groove that all the tensile stresses in the shaft reverse to compressive stresses above the retaining ring. Sketch A indicates these stress lines, and it is obvious that the most highly stressed part of the shaft is the fillet at the top of the groove. If the bracket is so stiff that any misalignment must be adjusted by flexure of the shaft, as indicated in sketch B, the compressive loads of the retaining ring will all be concentrated on one side as shown in C and C', and the load concentration will increase the stress on that portion of the fillet to many times its normal intensity; and as the point of concentration revolves with each

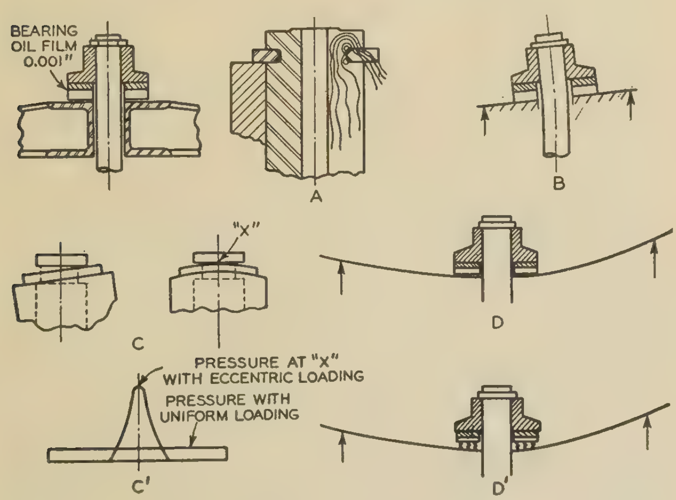


Figure 3. Elements of a typical thrust-block and retaining-ring design

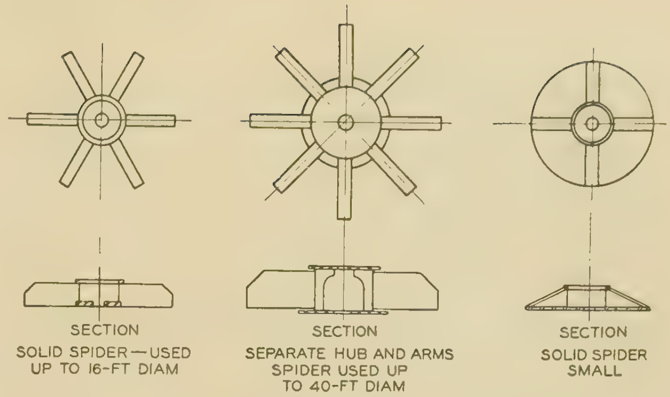


Figure 4. Arrangement of some spider-type brackets

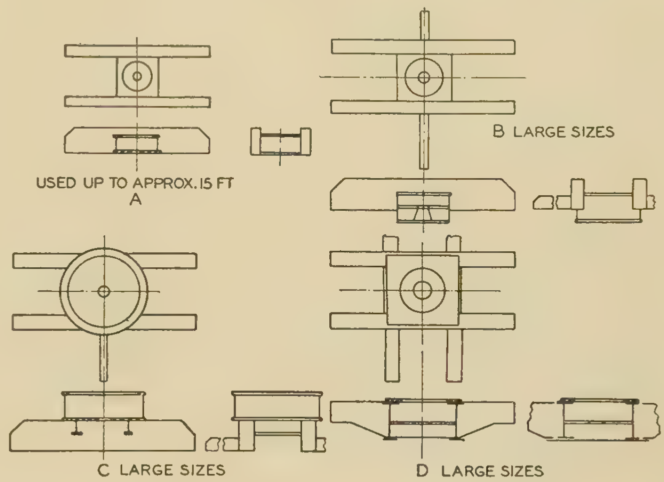


Figure 5. Arrangement of some girder-type brackets

revolution of the shaft, this sets up an ideal condition for a fatigue failure. As the thrust collar is usually a slide fit on the shaft, it too will work on its fit, forming rust which further loosens the fit. It is therefore highly undesirable to allow adjustment of the alignment of the thrust-bearing surfaces by bending of the shaft. A reasonable degree of flexibility in the bracket allows the bearing floor to align itself something like D and D'. This results in heavier loading on one side of the bearing than on the other, but not sufficient to cause concentrated stresses in the retaining ring. Naturally, nothing is completely rigid, and any misalignment will result in flexure of all the parts, shaft, collar, bearing, and bracket. It is desirable that as far as possible the greater portion of the flexure should occur in the stationary parts, such as the bearing and bracket, rather than in revolving parts, such as the shaft and collar; this distribution can be readily obtained by proper design proportions.

A degree of flexibility in the thrust-bearing support will allow a large proportion of the impact vibrations of the water wheels to be absorbed in the mass of the rotor instead of being transmitted undiminished to the babbitted surface of the thrust bearing. These impact vibrations occur in most wheels at certain gate openings; their effect is somewhat like heavy hammer blows on the shaft.

Bracket Design

While still on the subject of gravitational forces and brackets, it might be appropriate to sketch some types of brackets that have been used. In the field of rigid brackets, a few fundamental forms are altogether too rigid to be safely used except with a spring-supported bearing. These are the cone, pyramid, deep domes, or variations of these with panels cut in the surfaces. Some of these forms have been quite generally used in the past, but, fortunately, usually with small machines. In certain forms that can be readily obtained (for instance, domed boiler heads) they are still used, but usually with flexible bearings. Brackets in general use today are of the spider and parallel-girder types. Figure 4 shows the construction of some typical spider-type brackets and figure 5 shows the girder type. It may be noted that all these types are essentially of beam construction and are designed as such.

Whether the thrust is carried by the upper or lower

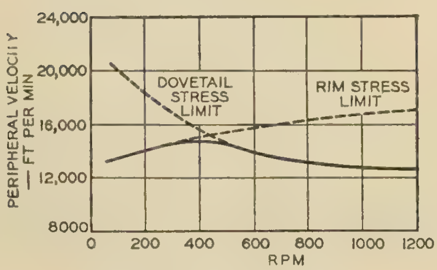


Figure 6. Peripheral velocities as limited by stresses in 60-cycle water-wheel generators

bracket, the design conforms with one of these general arrangements and is usually sufficiently stiff to satisfy the water-wheel manufacturer and sufficiently flexible to mount the thrust bearing properly.

Centrifugal Forces

The revolving part of an alternator is the field, largely because it can be better constructed to withstand cen-

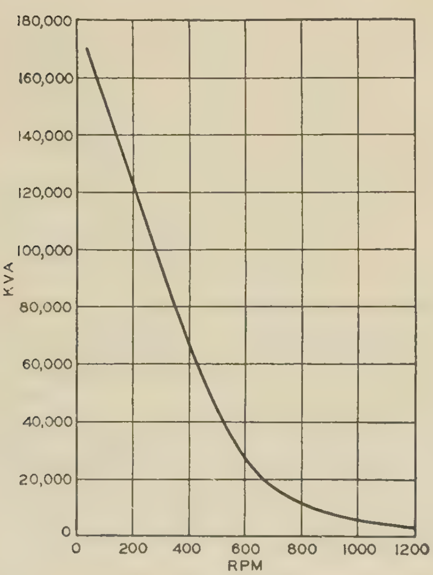


Figure 7. Maximum feasible rated capacity of salient-pole 60-cycle water-wheel generators

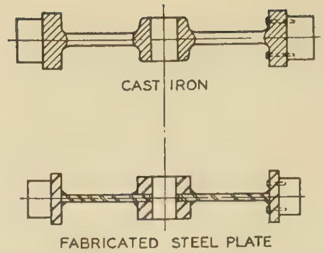


Figure 8. Construction of rotor with cast-iron or fabricated steel wheel

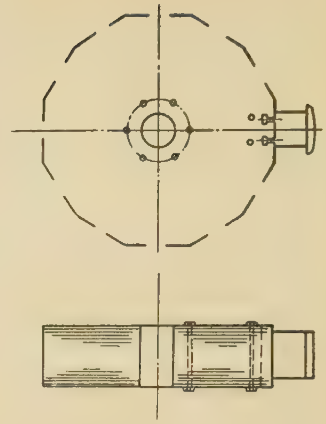


Figure 9 (right). Construction of rotor using stacked steel plates or sheets

trifugal forces. The two limiting features with regard to centrifugal forces are the dovetail stress (in the base of the poles where they dovetail into the rim of the rotor) and the rim stress. Figure 6 shows the normal limitation in this regard. These limits can be extended by the use of special alloy steels and unorthodox construction, but as yet the water-wheel manufacturers have not produced wheels that exceed these limits, except certain high-speed wheels.

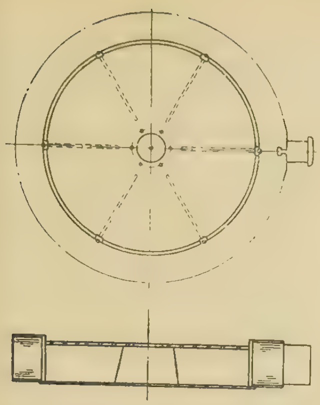
Figure 7 shows limits of maximum feasible kilovolt-ampere ratings of salient-pole generators based on standard construction. When comparing the possible ratings at high speeds with known steam-turbine capacities at these speeds, it must be remembered that water-wheel generators must withstand up to 100 per cent overspeed compared with 10 per cent for a turbine generator; consequently the maximum diameter is $(^{110}/_{200})^2$ or $^1/_3$ and maximum capacity $(^1/_3)^3$ or $^1/_{27}$ of that of a turbogenerator.

Rotor Construction

Centrifugal forces in the revolving parts are of fundamental importance in designing a machine, but as a rule they are not the limiting factors. While the methods of rotor construction are many, present practice on the American continent is to use variations of one of three types.

The first type used for small low-speed machines is a cast-iron or fabricated steel wheel with bolted poles (figure 8). The centrifugal forces are low in these rotors, and the design is based on obtaining a rigid structure requiring minimum machine work and lowest cost.

The second type is used for high-speed machines of medium and large capacities (figure 9). These are usually made of steel plate or sheet stacked as solid disks with dovetail grooves either machined or punched in the edge of the rotor to carry the dovetails of the poles. Cast-steel and forged-steel have been used for this type of rotor in the past, but today the low base price of steel sheet, and the ease with which it can be fabricated by gas cutting or punching makes sheet the most economical material. A laminated rotor is a desirable construction in any event, as centrifugal forces equally divide through



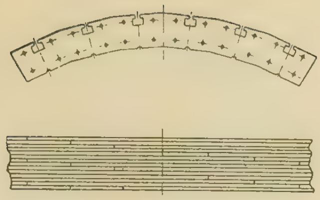


Figure 11. Construction of rim for rotor of figure 10

Figure 10 (left). Construction of rotor with laminated rim surrounding a central cast or fabricated steel spider

a number of complete disks. This results in equalization of stresses, and in the isolation of a possible flaw to the particular disk in which it may occur.

The third type of rotor is used for large, medium and low-speed machines. This consists of a laminated rim mounted around a central cast or fabricated steel spider (figure 10). The poles are either bolted or dovetailed to the rim, and the rim carries all the centrifugal forces of poles and rim. The spider is primarily a centering device to locate the rim, carry its weight, and transmit the driving torque to the rim, but carries no centrifugal forces other than that due to its own mass. The rim is made up of a series of segments punched from steel sheet, pinned and bolted together. The efficiency of the rim depends upon the proportion of joint to rim or to the minimum section between dovetails, bolts, holes, etc., and rim section. As the minimum section of a segment comes under a dovetail, the joints are located between dovetails (figure 11). Usual practice is to limit the stress at overspeed to one-third of the ultimate strength of the material used, or two-thirds of the yield point, whichever is lower. This type of rim has the desirable features of the disk-type rotor in that the stresses are equally and uniformly divided among a large number of independent segments, and a flaw in a segment is isolated to that individual segment. The working and rolling that sheet goes through gives sheet steel a uniformity impossible to obtain in castings and most forgings. Shear stresses in the rim are carried by ground steel pins and studs driven through the holes in the rim. Figure 12 is representative of small rotors of this type.

Strain is so intimately associated with stress that it seems proper to indicate here the amount that a rotor expands under centrifugal force even though it is not enough to be of practical significance. It amounts to about five mils per foot of diameter at the overspeed. On the largest machines built to date this does not amount to more than 20 per cent of the air gap and at normal speed, when it might have an effect on the excitation characteristics, it is less than 5 per cent of the air gap.

The poles usually are fastened to the rotor by means of dovetails in the bottom of the poles which are ordinarily of one of two types, V or T. Each of these has its own peculiar virtues, as may be seen in figure 13, which shows both types of construction and how they fail. With both types, unless supported by welding across the bottom surface, failure starts by crumpling of the laminations at the bottom of the dovetails and then tearing in the fillets. The V dovetail is shallower than the T, permitting greater depth of useful rim section, but it has a side wedging action that adds to the rim stress under the dovetail. Hence the proper field of the V dovetail is where the dovetail stresses are low, causing low wedging stresses, and the rim stresses are high thereby securing best utilization of the rim material. The T dovetail has no side thrust, and the long neck stretches sufficiently to equalize the load between dovetails; therefore T dovetails are used singly or in parallel where the pole stresses are high compared with the rim stresses.

No consideration of centrifugal forces would be complete without some reference to unbalance. On the drafting board the rotor, of course, is balanced; however because of variations in thickness of steel and usual tolerances of purchasing or shop practice the rotor may not necessarily be balanced when built. If the rotor is small enough to be assembled and built at the factory it can be balanced there on balancing ways or pivots. In the field it can be balanced in its own bearings by means of special equipment, but this latter method has not much to recommend it. It is a relatively simple matter to balance the spider of the rotor at the factory. The rim punchings can be segregated in groups of segments of the same weight, and piled so that each circle is of punchings of the same weight which should result in a balanced rim. The poles and coils can be individually weighed and located so that they are balanced about the rim. This procedure should produce a balanced rotor, and experience so far indicates that it does.

These are the main problems due to centrifugal forces; there are others—the attachment of all members to the rotor parts, fans, brake plates, coils, coil leads, etc., whirling of oil in the bearing housings, whirling of air in the machine, etc., which are too specific for a general survey.

Magnetic Forces

The other major force is magnetic. The fundamental characteristic of the magnetic pull is that it varies as the square of the flux density. The flux density is determined by the sum of the stator and rotor ampere turns divided

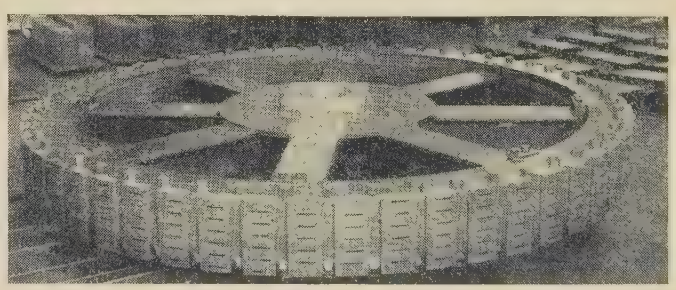


Figure 12. A rotor of the type shown in figures 10 and 11

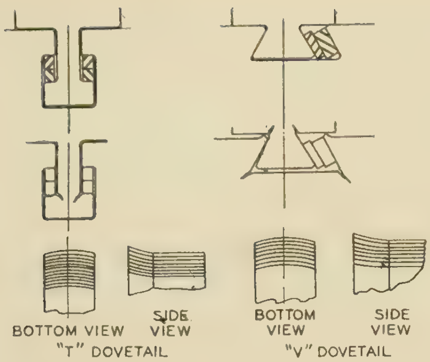


Figure 13. Details of V and T dovetails, and points where failure usually occurs

by the reluctance of the magnetic circuit. This, under normal operating conditions, causes a constant radial magnetic pull between the rotor and stator of about 25 pounds per square inch. If the rotor and stator are concentric circles and the stator and rotor ampere turns are balanced around the periphery, these forces are sustained by compression in the stator core and tension in the rotor rim. However, if the rotor and stator are eccentric, the reluctance will be unbalanced, and there will result an unbalanced magnetic pull that is proportional to the eccentricity, which must be resisted by the guide bearings and the arch and beam strength of the frame. Coils open or short circuited on one side of the core or rotor also will give rise to unbalanced magnetic forces. The design of the guide bearings and their supporting structure is one that must be determined by the extent and probability of occurrence of these unbalanced conditions.

The normal magnetic forces on a generator frame result in compression of the core and frame; like any compression-loaded structure, any unbalanced reaction should be kept within the middle third even though the frame has additional stiffness as a beam. This condition is particularly critical for a force such as magnetic pull which unlike gravity increases directly as the deflection. Thus if a frame is not stiff enough and tends to collapse into, say, an elliptical form, the magnetic forces causing this collapse increase to the extent that stress in the frame increases; consequently the frame will collapse completely against the rotor. Because of this characteristic the frame should be made so that it will collapse to a stronger position if possible. This can be done by securely clamping the core and anchoring it to the frame and doweling the frame to foundation plates anchored in the floor.

In addition to radial pull, there is the torque resulting from the angular displacement of the rotor under load. This displacement is proportional to the load and reacts as a side pull on the poles and coils in the slots. Under normal conditions, this does not amount to much so far as these parts are concerned. If the stator coils are loose in the slots it may cause them to vibrate and become looser, but main strain on the machine comes in case of an instantaneous short circuit or bad synchronizing shot. Under such circumstances the rotor must change its angular position to agree with the new conditions. The force available to do this is limited only by the extent of the reactance of the machine, which limits the stator current, and the force may amount to ten times the normal torque of the machine. The reaction to this force is the acceleration of the inertias of the rotor and stator and the shear of the dowels holding the stator to the foundation. In case of synchronizing out of phase it is possible to have polarity of the stator opposed to polarity of the rotor and a repulsive force exerted between the rotor and stator, tending to burst the stator; therefore any joint in the stator must be designed to withstand bursting as well as compressive stresses. A single-phase short circuit causes negative as well as positive torques which shake the machines at twice their rated frequency. Large single-phase generators are mounted on springs so that the negative forces are absorbed in the vibration of the frame instead of being transmitted to the power house.

Another manifestation of magnetic force is found in the force between coil sides. This varies as the square of the current, attracting when currents flow in the same direction and repelling when in opposite directions. In the slots the coils are surrounded by iron and so are well anchored, but in the end connections they are held mainly by the stiffness of the conductor plus suitable blocking and lashing to prevent dangerous movement.

Natural Frequencies of Vibration

While dealing with gravitational, centrifugal, and magnetic forces, it would be an appropriate time to mention natural frequencies. Any mass acted on by a force that varies with displacement has a natural frequency of vibration. If this natural frequency does not coincide with some forced frequency in the machine no trouble occurs. However, parts that might vibrate at a forced frequency must be checked. These are the upper bracket carrying the rotor vertically against gravity and the shaft bearings and brackets supporting the rotor sideways, which must be checked to see that the critical speed is greater than the overspeed of the unit. Because magnetic pull acts to increase deflection this frequency is lower when the machine is excited than when not excited. The rotor has a torsional natural frequency (when operated on a system) depending on the inertia of the rotor and the displacement angle of the load. Two inertias such as a

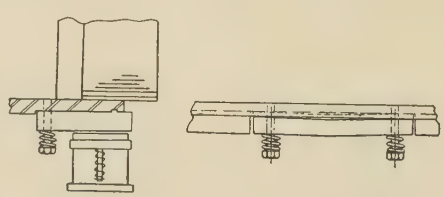


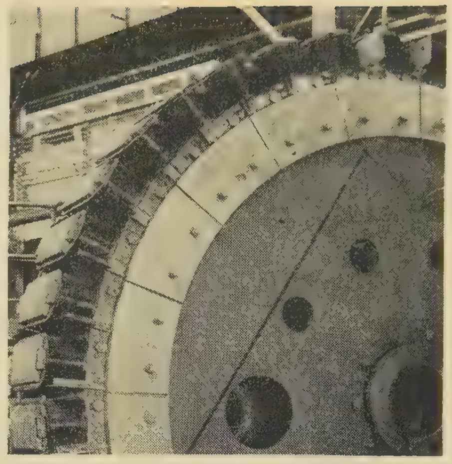
Figure 14. Method of attaching brake shoes to rotor

rotor and flywheel on the same shaft have a natural frequency of oscillation. Other parts, such as fans, core bolts, cover plates, and pipes have natural periods of vibration; if the frequencies of these vibrations coincide with a forced frequency of the generator, such as a harmonic of the speed of revolution or frequency, dangerous stresses or objectionable noises in these parts may result.

Magnetic noise in an alternator is a result of forced vibrations in the audible region, caused by inequalities in

the magnetic circuit. The stator core contains a number of slots, and it is apparent that at a certain slot position the path for most of the flux will be from a pole to the teeth. Thus every time a pole passes a slot there will be a change of this pull from maximum to minimum and back again. The frequency of this variation in pull will depend on the number of slots per pole and will be in the order of 15 to 50 times the line frequency, which is right in the audible range. To prevent this variation in magnetic pull from causing objectionable noise, the pole face should be designed to cause a minimum variation in magnetic pull, and the number of slots should be selected so that a large number of adjacent poles will not exert maximum and minimum pull at the same time, causing the frame to vibrate in distinct nodes.

Figure 15. Portion of a typical rotor showing braking surface



Thermal-Expansion Forces

The other force requiring attention is that resulting from thermal expansion. If constrained, this force, in steel members, amounts to 340 pounds per square inch per degree centigrade rise. If not constrained, the expansion is approximately 0.135 mils per foot per degree centigrade rise. A 30-foot stator frame with an average rise in temperature of 25 degrees centigrade throughout the core will expand a tenth of an inch in diameter. If the frame is held constrained by fixed dowels, high stresses will be exerted on the dowel and the core iron will crumple up in waves around the core. A better method is to dowel the stator radially so that the frame is free to expand radially but remains concentric and is firmly keyed against twisting.

The rotor and stator windings are also subject to strain and stress from differential thermal expansions, and, like the frame, it has been found best to design the insulation and supports so that movement can occur to relieve the stresses. The rotor coils, which are bare copper, take care of themselves if the top collars are strong enough to withstand the coils sliding against them under the pressure of their centrifugal forces. The stator coils, however, are covered with insulation that is relatively cool on the outside but hot enough inside for a coil four feet long to expand about $^1/_{32}$ inch; the insulation must follow the conductor without damage. It has been found that plastic varnish of the asphaltic-base type, when used as sticker between layers of tape, is sufficiently plastic to follow the copper without damage to the insulation.

An interesting example of thermal strains is found in the brake surfaces. This is the surface on the bottom of the rotor against which friction brakes are applied to bring the machine to a quick stop. The friction of braking generates heat that is absorbed by the brake surface, and in the case of a rapid stop the temperature of this surface can easily reach 200 or 300 degrees centigrade before any of the heat can flow into the rim back of the surface (figure 14). This surface tries to expand but cannot if it is part of a solid cold rim, so at the high temperature it is crushed beyond its elastic limit; when it cools, it is stretched beyond its elastic limit. After a number of cycles, cracks begin to appear in the surface. The present solution of this problem is to use small segments and mount them with a spring support so that the plates can expand when hot and return to their original shape when cool. The use of cast iron instead of steel for these surfaces gives better thermal characteristics as well as a superior braking surface. Figure 15 shows such a brake surface.

Mechanical Design Affects Other Characteristics

The foregoing has been mainly a description of how the gravitational, centrifugal, magnetic, and thermal stresses affect the mechanical construction. The mechanical construction in turn affects the electrical and thermal characteristics. Thus while theoretically the D^2L of a machine (D is its diameter and L its length) remains a constant for a certain output and speed through variations of diameter, actually it varies in a series of steps because of the necessity of using an integral number of turns per coil and a suitable number of slots in the stator. The most economical design of generator can be made for those speeds at which the number of poles is divisible by four or six without leaving a factor of three in the answer.

There are certain generator proportions that result in economic electrical design; for instance, the core length should be between one and four times the pole pitch. A shorter core than this, although sometimes necessary in 25-cycle machines, results in a pancake structure that is all frame, spider, brackets, and end connections. Should the required flywheel effect be so large that the electrical proportions are poor, it is usually best to design for the most suitable electrical proportions and obtain the flywheel effect in a separate flywheel. If, however, the required flywheel effect is so low that core length exceeds the four-to-one ratio, it is usually best to design to this ratio, as the difficulties in ventilating a longer core will cost more than the additional rim material.

Cooling

The losses in a generator removed by the cooling air are the resistive (I^2R) losses in the windings and the losses in the core. Bearing losses usually are removed from the

oil by cooling coils in which water is circulated. The losses in a generator usually are limited by the efficiency rather than the heat-dissipating performance, and the size of the machine usually is determined by magnetizing and reactance limitations so the problem of cooling a machine usually devolves into one of dissipating a known amount of heat from a machine of a known size. The coolant is air; although water or special gases could be used, the expense is not justified.

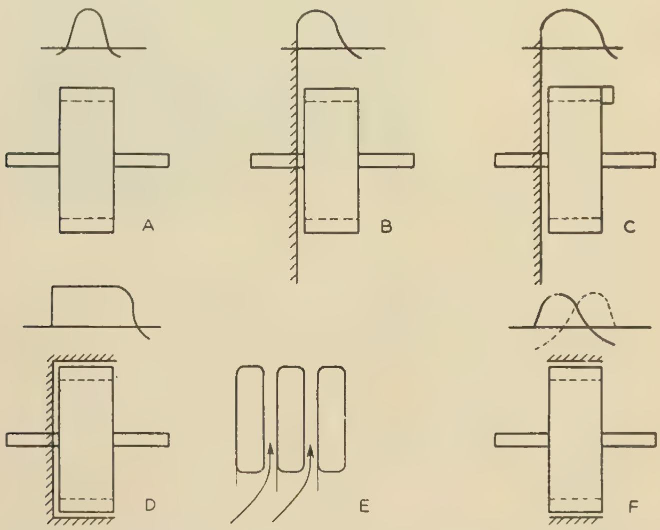


Figure 16. Air-pressure curves for a spinning rotor under various conditions

It has been almost standard practice to require that the generators be self-ventilating and usually they are. The maximum pressure available to force the air through the core depends upon the peripheral speed of the rotor and the mass of the rotating column of air back of it. Unlike a blower where the air can enter the center and progress radially outward through the blades, in the generator the poles are the blades and the air must enter at right angles to the pressure generated by the rotating surface and again reverse direction to exhaust through the ducts. The ducts are by no means an ideal collector. In essence, the problem of ventilation is one of adding gadgets here and there attempting to turn the generator into a passable blower.

The curve of natural pressure of a rotor spun in open air has a shape like A, figure 16. If one end is blocked as shown in B, the maximum pressure point approaches that end and the pressure at the other end becomes negative. If the poles are extended on the negative end as shown in C, a positive pressure can be secured over the full length of core. This pressure distribution is not materially changed by placing a core over the rotor provided the ducts are large enough to exhaust all the air that can get in between the poles. If the stator is solid and the end blocked, the pressure curve flattens out and air is recirculated as shown in D. Thus by changing conditions it is possible to change the shape of the pressure curve but not its maximum value. Vertical-shaft generators are essentially single-end-ventilated machines like B, C, and D. To obtain a uniform pressure through the core, fan blades can be added to the open end and the exhaust from the high-pressure ducts restricted. This last expedient is undesirable unless it is impossible to secure sufficient air through the open-end ducts by other means such as use of fans, larger ducts at the open end, and throttling of the exhaust through the end connections at the closed end.

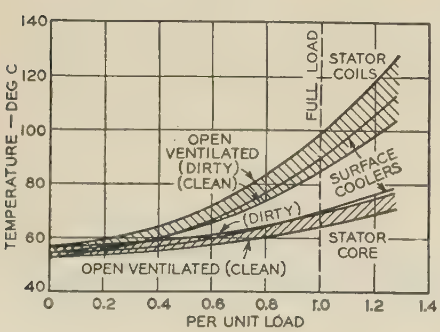


Figure 17. Temperature rises of open-ventilated generators and generators with closed ventilation through surface coolers (based on maximum Canadian ambients)

As an expedient to reduce the entrance losses between poles and to project the pressure curve toward the open end, fan blades as shown in E have been found most effective. Where deep blades are required they work best on alternate poles.

It is possible to get the air to pass through the rotor arms to the closed end of the rotor and shift the point of maximum pressure nearer to the center of the core, but to do this requires scoop blades in the bottom of the rotor to overcome the resistance of the air path through the rotor and around the corners. If this is not done the difference in pressures at the closed end and the open end will prevent any appreciable air from entering the poles from the closed end. The pressure curve shown in A, when the rotor is surrounded by a core, is particularly sensitive to pressure changes on the ends. In a horizontal machine with this type of ventilation the pressure will shift from end to end as shown in F by a change in direction of wind unless central interpolar baffles or stabilizing fans are used.

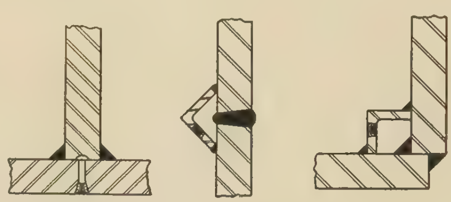


Figure 18. Arrangements for pressure testing of welds for oil-tightness

The addition of surface coolers or an elaborate duct system to a generator results in a constant back pressure that must be subtracted from the pressure curve. Consequently to get adequate ventilation through the core, the pressure curve must be flatter than for an open-ventilated machine, and some parts such as the end connections may have to be ventilated separately by means of recirculation and dilution of the cooling air.

The usual temperature limit of a generator is 60-degrees-centigrade rise, and the minimum amount of cooling air is usually set at 100 cubic feet per minute per kilowatt loss, which results in an 18-degree-centigrade rise of the

cooling air. As the total losses will amount to $2^1/_2$ to 5 per cent of the machine rating, the average machine will pass 10 to 20 times its own weight of air through it per day; consequently a very small proportion of dirt in the air may cause quite an accumulation of dirt in the machine. This dirt will form in layers interposed like a sheet of felt between coils and core to be cooled and the cooling air. Consequently a higher temperature is necessary in the coils and core to maintain the same heat flow to the air. A dirty machine usually will be at least 10 degrees centigrade hotter than when clean; a filthy machine may have to be operated at considerably reduced load.

There is no perfect solution of this dirt problem. Where atmospheric conditions are bad, the best solution is to recirculate the air through the machine and surface coolers. This stops the build up of dirt, but the temperature of the cooling air is usually higher than atmospheric; consequently the operating temperature of the machine is higher than that of a clean open-ventilated machine but lower than that of a dirty open-ventilated machine. However, the advantage of a closed ventilating system is not so much in the improvement in the actual operating temperatures as that the temperature rise is considerably lower and that hot spots caused by complete blockage of ducts are prevented.

Figure 17 shows a comparison of temperature and temperature rises in a closed machine with 25-degree water and an open machine with 35-degree air. It may be noted that the main difference lies in the temperature rise of the coils.

In winter, only a part of the cooling air is taken from outside, and the rest recirculated in the powerhouse; hence most of the dirt gets in the machine in the summer. Flies and oil are the two worst offenders in clogging the ventilation of a machine. Flies, lint, and similar fibrous material cling around the sharp edges of the duct like driftwood around a pier and gradually close off the entrance to the ducts. Oil will wet the surfaces of the ducts so that dry dust that would otherwise blow through clings to it, filling the ducts in any place where air velocities are low. For maximum flow through a duct with minimum dirt accumulation, the duct entrance should be made something like a ship's ventilator. This is not practicable, but some improvement has been made by making the wedge to slope into the duct and curving the spaceblock tip in the direction of rotation. Dirt builds up on the edges and surface of this type of duct too, but as the entrance area is larger it does not close them to the same extent.

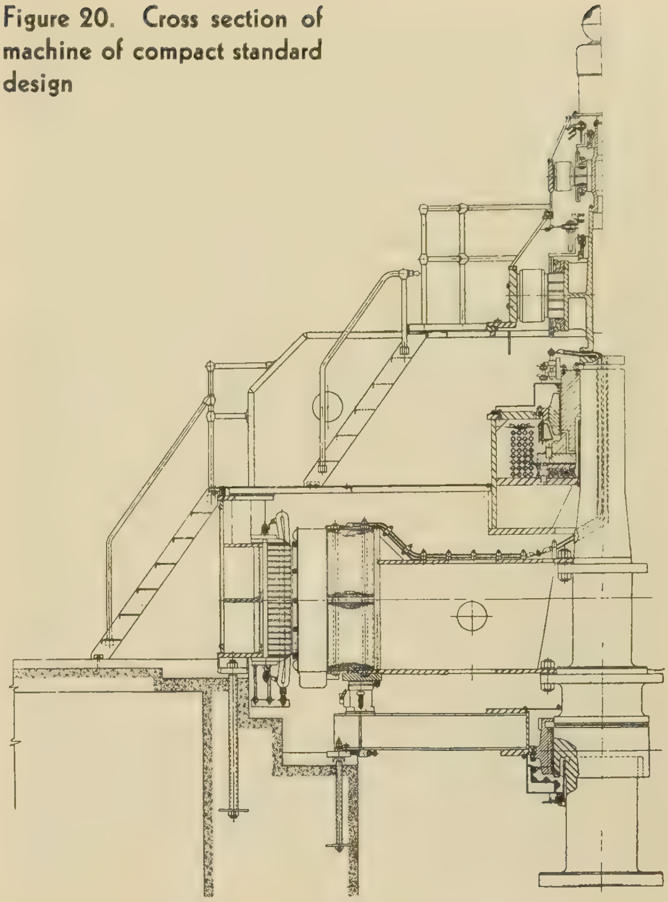


Figure 20. Cross section of machine of compact standard design

Keeping Oil Out of the Windings

How to keep oil out of the windings of machines and in the bearings where it belongs is a problem as old as generators themselves. The problem splits itself into

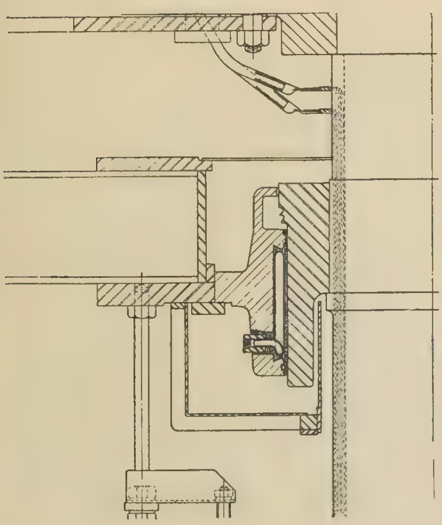


Figure 19. Cross section of bearing in which formation of oil vapor is practically prevented

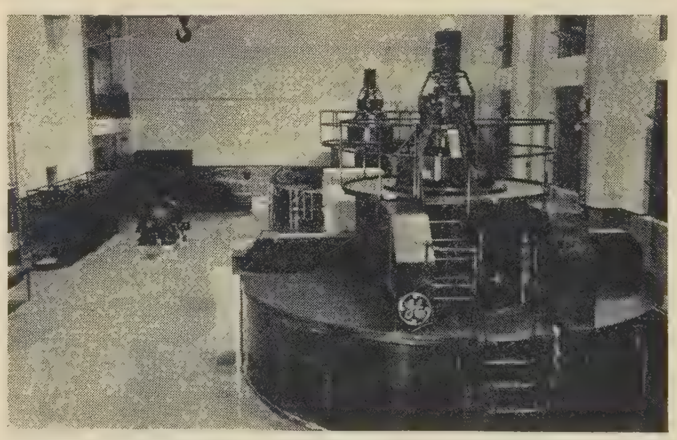


Figure 21. Two 26,315-kva 180-rpm 60-cycle generators of the type shown in figure 20

two categories: The first is to keep the oil from leaking through castings, welds, gaskets, pipe joints, or overflowing, spilling, or syphoning down the shaft. The second is to keep oil vapor enclosed inside the bearing housing, with air blowing past it into the generator.

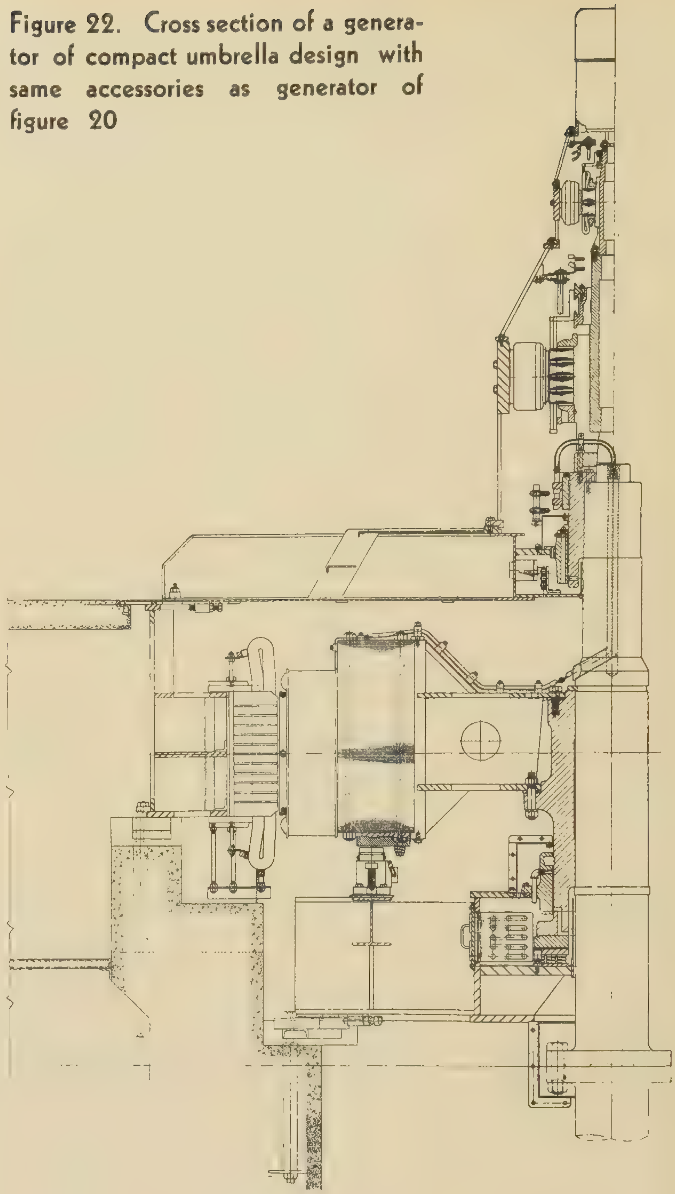
The problem of leaky castings can be solved by only one method—sound castings. If the source of the leak can be discovered, it is sometimes possible to chip it out and braze a plug over it. Oilproof paints, galvanizing, tinning, etc., will all open up in time. The reason very few leaks can be permanently cured is that the castings in which the leaks occur are continually in a state of vibration, and the surface tension of oil to iron is such that once the surface is wet with oil it is almost impossible to dislodge the oil without boiling it out and carbonizing the residue. The vibration works the oil out of a crack or leak like working a nail out of a piece of wood. The surface tension is such that the oil will climb as much as a foot up a crack against gravity.

An alternative is to use welded-plate construction instead of castings. Fortunately, the plates themselves are oiltight, at least crosswise; the welds, however, are a different matter. In running a long weld, strains are set up that sometimes cause transverse cracks. This is particularly true in corners. These cracks may not impair the weld from the viewpoint of mechanical strength, but will make a beautiful leak which may start at some crack inside the oil housing and come out through another crack perhaps ten feet away. It may take a week or six months for such a leak to show up, and then drip, drip. After some experience, a technique has been developed that seems to have this problem solved. The first thing is to avoid welding into corners, and the second, to use double oiltight welds. See figure 18. A pipe tap is run into a longitudinal channel cut in the plate, and between the welds. These welds are tested up to and beyond their working stress with hydraulic pressure, which may amount to 1,500 to 2,000 pounds per square inch, and if it holds this pressure for several hours it is considered satisfactory. Sometimes it is easier to weld an angle on the inside and test in the same way.

Gasketed joints below the oil level should be avoided if possible. If necessary, heavy flanges should be used, with closely spaced bolts or studs, and the gasket should be placed on the oil side of the bolt circle (not on both sides as it is quite possible to tighten up on the wrong side). The packing should have characteristics suitable for the job—cork will be satisfactory when no additional load is to be carried, but must be gradually compressed to its final set; for joints that must carry additional load such as exciters, a treated paper-base packing will maintain alignment much better. One of the best methods of sealing is to paint the gaskets and joints with red glyptal paint and dry until tacky and then assemble. This gasket will be destroyed when the joint is separated, but is usually oiltight.

Pipe joints and fittings should be avoided. Where piping is necessary, brass pipe assembled with all screw threads sweated with solder, or copper tube with soldered fittings are the most reliable. Couplings should be of the flange type, and the gaskets treated as previously described.

Figure 22. Cross section of a generator of compact umbrella design with same accessories as generator of figure 20



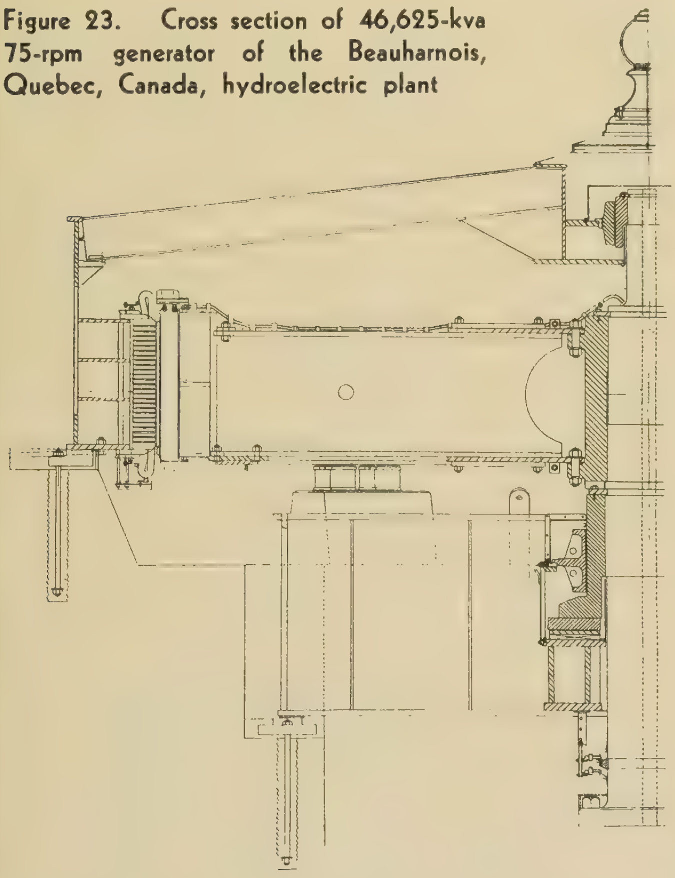
Oil leakage by overflowing, spilling, or syphoning down the shaft can be avoided by proper design of bearing parts, concentricity of the oil tube, and proper venting of the bearing.

The problem of preventing the leakage of oil vapor out of the bearing housings has eventually reduced itself to one of preventing the formation of oil vapor. Figure 19 illustrates a type of bearing in which the formation of oil vapor is pretty well prevented. These bearings are self-lubricating—no external oil feed or drain is necessary to lubricate them. They run against sleeves that dip below the oil level. Holes in these sleeves cause oil to be thrown by centrifugal force into the bearing, where it works up through oil grooves to the top and here overflows and returns through passages back to the oil reservoir below the oil level. The surface of the oil is kept still except for a certain turbulence resulting from the oil circulating below, and quite cool by the immersed cooling coils; hence very little or no vapor forms. The air space above the

oil is vented by a $^{1}/_{16}$-inch hole, and except for this there is no way for air to get in or out of the bearing housing. As this type of bearing requires no external oil circulation, there are no pipes to leak, no drains to clog with cold oil and overflow the bearings, nor similar troubles.

Oil may be considered in the same light as an explosive—highly necessary where required, but a potential danger any place else. The duty required of oil for the bearings of a vertical-shaft generator is no more severe than in the ordinary ring-lubricated journal bearing, and the same degree of care of the oil should suffice. Oil-circulating systems introduce a hazard to the rest of the machine that is hard to justify on the basis of oil maintenance. Dust in an open-ventilated machine cannot be prevented, but if it is not caked on with oil can usually be readily cleaned off. As the greatest obstruction to the air flow occurs at the surface of the core, the first essential in cleaning a machine is to clean off this dust by a brush between the poles. The rest can be readily blown out.

Figure 23. Cross section of 46,625-kva 75-rpm generator of the Beauharnois, Quebec, Canada, hydroelectric plant



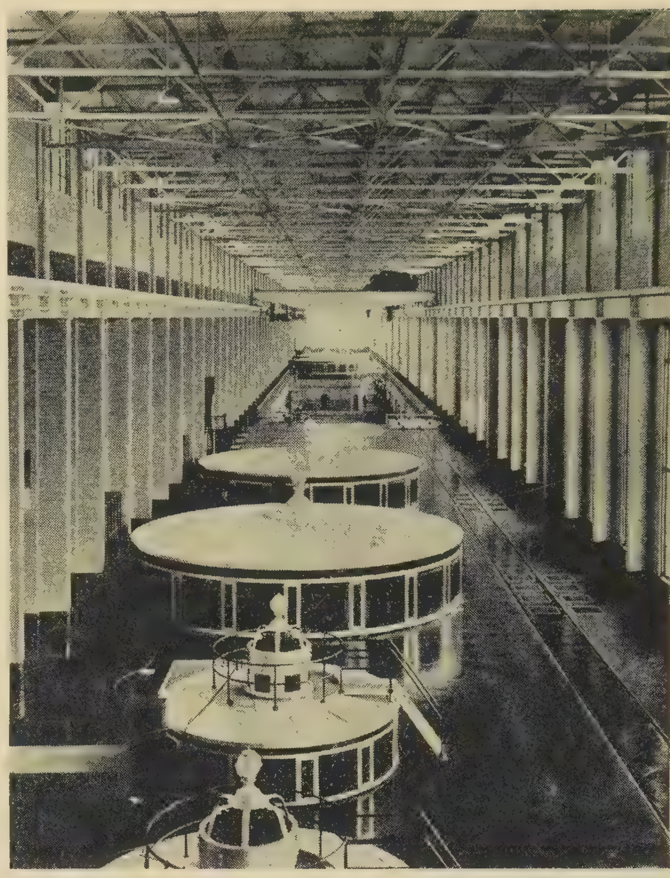


Figure 24. Interior of the Beauharnois plant, with main generators of the type shown in figure 23

Individuality of Design

The arrangement of an alternator as to whether the thrust bearing is mounted above or below, whether one or two guide bearings are used, whether the machine ventilates from the top or bottom, is open ventilated or closed ventilated, is a problem that usually is determined by the hydraulic or civil engineering aspects of the power-house design. The alternator designer's problem is to take the limitations set down for him and make a safe and workable design if possible, and if not to suggest suitable modifications that will result in good design.

Figure 20 shows a compact standard design and figure 21, a view of the installed machine. Figure 22 shows a compact umbrella design with the same number of accessories on top. The only difference is the location of the stator with regard to the coupling face.

Figure 23 shows a section of the 46,625-kva, 75-rpm generator at Beauharnois, Quebec, Canada, and figure 24 an installed view.

An installed view of the 48,500-kva generators at Abitibi Canyon, Ontario, Canada, is shown in the headpiece of this article. These machines have a complete air-circulating system.

These illustrations are not intended to portray any significant trend in design. If anything, they indicate the utter individuality of design of generators built by just one company within a short period of time. Certain fundamental problems are common to all vertical-shaft generators and in these there is a certain continuity of progress of solution as experience and research supply the designer with a better appreciation of the factors of the problems and as advances in technology open avenues of promising construction methods. The other problems are usually peculiar to the particular generator under consideration. As each power site has individual characteristics, such an important item in the development as the generators must be moulded to best fit the power-house requirements.

News

Of Institute and Related Activities

Great Lakes District Holds Sixth General Meeting at Minneapolis

FOR the sixth general meeting of the Great Lakes District, held at the Nicollet Hotel in Minneapolis, Minn., September 27–29 inclusive, the Minnesota Section served as host. Although a majority of the approximately 90 members of this Section reside in the St. Paul-Minneapolis metropolitan area, the Section territory embraces not only all of the state of Minnesota but a double tier of the ten northwesterly counties of Wisconsin. The District itself embraces the six states of Michigan, Indiana, Illinois, Iowa, Wisconsin, and Minnesota, and its "center of gravity" of membership in so far as members are concerned is in the vicinity of Chicago, some 400 miles south and east of Minneapolis. Considering this factor of distance, and considering also the American Legion convention in Chicago and the utilities convention in Indiana held the same week, the total attendance of 230 at Minneapolis, including 141 from outside the Section territory, constituted a worthwhile achievement in the opinion of observers, especially in view of the unusually high percentage of attendance at the several very active student and technical sessions.

Attendance at technical sessions ranged from 55 to 110, averaging about 80. All such sessions were held during the forenoon—two in parallel on each of the first two days; the afternoons being devoted to inspection trips and other activities.

President Farmer spoke briefly before both the student and the general session groups, commenting on various aspects of Institute activities and pointing out the opportunities for professional as well as individual development provided within their scope. As general chairman of the District meeting committee, Dean A. H. Lovell of Ann Arbor, Mich., vice-president for the Great Lakes District, took an active part in all activities. A representative from the office of Governor Harold E. Stassen presented a message of welcome at the opening session.

Principal feature of the entertainment program was a dinner and dance held Thursday evening at the headquarters hotel, attended by 169 members and guests. Following the dinner and preceding the dancing, Doctor Phillips Thomas, research engineer of the Westinghouse Electric and Manufacturing Company, gave an hour's animated lecture demonstrating some of the products and discoveries of the research laboratories. A group of about 36 took advantage of a 90-mile sight-seeing tour around Minneapolis, St. Paul, and vicinity Wednesday afternoon, joining some 65 others for dinner that evening at the country house of the Automobile Club of Minneapolis at Bloomington-on-the-Minnesota.

Doctor William Austin O'Brien, noted pathologist of the University of Minnesota, addressed an audience of about 100 gathered for a Wednesday noon luncheon held at the Hotel Nicollet in conjunction with the Minneapolis Engineers Club and the St. Paul Engineers Society. Doctor O'Brien drew attention to the close similarity in the basic characteristics of students starting out for a career either in modern medicine or electrical engineering. Speaking of electrical equipment in the service of medicine, Doctor O'Brien described the X-ray as one of the greatest known diagnostic facilities, and one also important in certain treatments.

Analysis of Registration at Minneapolis

Membership 8/1/39	Sections	Members	Enrolled Students	Men Guests	Women Guests	Totals
126	Central Indiana	6	6	0	1	13
733	Chicago	16	7	5	1	29
98	Fort Wayne	5	1	0	0	6
67	Iowa	9	4	0	0	13
65	Madison	6	6	3	3	18
358	Michigan	7	3	0	0	10
270	Milwaukee	8	8	1	2	19
89	Minnesota	43	15	14	17	89
77	Urbana	6	3	1	0	10
		106	53	24	24	207
From Outside District 5						
56	Nebraska	0	1	0	0	1
3,355	New York	6	0	1	1	8
517	Pittsburgh	5	0	0	0	5
403	Schenectady	4	0	0	0	4
153	Seattle	1	0	0	0	1
	Non-Section Territory	2	2	0	0	4
		18	3	1	1	23
Totals		124	56	25	25	230

He mentioned the use of the photoelectric cell for close and accurate color comparison in the analysis of solutions, and mentioned as the most ingenious class of equipment the whole range of electrically lighted "scopes" by means of which the modern medical practitioner is able actually to look inside the human body.

Inspection trips supplementing the technical program included visits to several of the large local flour mills, various plants and system facilities of the Northern States Power Company, manufacturing establishments such as those of The Electric Machinery Company, The Minneapolis-Honeywell Heat Regulator Company, the Minnesota Mining and Manufacturing Company, and, of course, the campus of the University of Minnesota including the enormous new hydraulics laboratory at St. Anthony's Falls of the Mississippi River right in the heart of the city.

Student Technical Sessions

In spite of the fact that many of the schools in the District were not fully in operation for the fall term by the time of the Minneapolis meeting, 56 students were registered. Although the student technical session was held in parallel with the Thursday morning general technical session, attendance at the student meeting was in excess of 75. Arrangements for student papers were made under the leadership of Professor J. H. Kuhlman, Branch counselor at the University of Minnesota. The following group of student papers was presented at a session presided over by Professor J. H. Bowman of Purdue University, current chairman of the Great Lakes District committee on student activities:

HIGH FIELD ELECTRON EMISSION, **Conrad H. Hoeppner**, University of Wisconsin.

MODULATION OF INCANDESCENT LAMPS, **John W. Smith** and **Max D. Liston**, University of Minnesota.

FETAL HEART BEAT RECORDER, **W. C. Morrison**, graduate student, State University of Iowa.

THE AUTOMATIC SOS ALARM, **Paul L. Schmidt**, Iowa State College.

ELECTRIC FENCE CONTROLLER CHARACTERISTICS, **Roger E. Schuette**, University of Wisconsin.

HISTORY AND PROBLEMS OF THE RURAL ELECTRIFICATION ADMINISTRATION, **Dale H. Scott**, Iowa State College.

A STATISTICAL ANALYSIS OF ELECTRICAL POWER PRODUCTION IN THE UNITED STATES, 1925–37, **Robert E. McDonald**, University of Minnesota.

A NEW INSULATOR AND ITS PLACE IN PRESENT ENGINEERING PRACTICE, **J. Sukup**, Marquette University.

A BALLISTIC METER FOR MEASURING TIME AND SPEED, **H. Toomin**, University of Illinois.

THE THEORY, CONSTRUCTION, AND TEST OF AN ICOSAHEDRON PHOTOMETER, **R. J. Diefenthaler**, University of Illinois.

TENSORS FOR ELECTRICAL ENGINEERS, **Vernon Tollefsrud**, University of Minnesota.

NOMOGRAPHY FOR ELECTRICAL ENGINEERS, **G. Ferrara**, University of Detroit.

THE ADVANTAGES OF THE CO-OPERATIVE SYSTEM OF ENGINEERING EDUCATION, **J. Price**, University of Detroit.

The following student papers were presented by title only inasmuch as the authors were not present:

A NEW ELECTRONIC VOLTAGE REGULATOR, **A. V. Donnelly**, State University of Iowa.

PROBLEMS IN FACSIMILE DESIGN, **Robert E. Holtz**, University of Wisconsin.

NYA AS VIEWED BY AN ENGINEERING STUDENT, **F. A. Glassow**, University of Wisconsin.

ECONOMIC CORNICE LIGHTING FROM SINGLE LARGE

Lamps, **W. M. Lomonoss** and **H. H. Hayes**, graduate student, University of Michigan.

A Simple Graphical Method of Finding the Illumination Values From Tubular Ribbon, and Surface Sources, **E. H. Wakefield**, graduate student, University of Michigan.

Conference on Student Activities

To serve as a medium of exchange for Student Branch operating experiences, and for the purpose of discussing District plans for student activities during the forthcoming academic year, a luncheon conference was held Thursday noon. In effect this was a joint meeting of the Great Lakes District committee on student activities and representatives from Student Branches in the District.

Among the Branch activities reported upon by various student chairmen, the following appeared to bear the stamp of success: Occasional inspection trips to points of technical interest; joint meetings between two or more Branches for competitive presentation of student papers; occasional social meetings; electrical-engineering "shows," frequently for the benefit of the general public. The reports indicated that technical papers presented at Branch meetings by students are becoming more popular and effective, although opinion was not unanimous. Such a trend was emphasized by some as being of particular importance to the individual student as well as to the strength of the Branch as a whole. One Student Branch has a football team.

Considerable discussion concerning the character of Branch membership revealed that within the District the percentages ranged all the way from 10 per cent national and 90 per cent "local" to 75 per cent national and 25 per cent local. The consensus of those most experienced in the conduct of Student Branch affairs was strongly in favor of placing the emphasis on the regular enrollment of student members instead of on the so-called local members.

The group took action in support of a 1940 District student conference, probably some time in October, the matter of place, date, and other arrangements being left to the executive committee for subsequent determination.

Action was taken to ask the AIEE committee on Student Branches to make a further study into the matter of possibly extending the period of time after graduation during which an Enrolled Student may transfer to full membership.

For three-year terms of service on the executive committee of the District committee on student activities, Branch Counselor G. F. Corcoran of the University of Iowa was elected to take office retroactively as of August 1, 1939, and Branch Counselor R. R. Benedict of the University of Wisconsin was elected to take office August 1, 1940.

Of the 17 Student Branches in the Great Lakes District, 16 were represented at the conference by a total of 34 faculty or student members, of which the following constituted the official delegates:

Student Branch Counselors and Alternates

Armour Institute of Technology, Chicago, Ill., E. H. Freeman

Detroit, University of, Detroit, Mich., H. O. Warner

Illinois, University of, Urbana, Ill., E. A. Reid

Iowa State College, Ames, Iowa, B. S. Willis

Iowa, University of, Iowa City, Iowa, G. F. Corcoran

Marquette University, Milwaukee, Wis., E. W. Kane

Michigan College of Mining and Technology, Houghton, Mich., G. W. Swensen

Michigan State College, East Lansing, Mich., M. M. Cory

Michigan, University of, Ann Arbor, Mich., S. S. Attwood

Milwaukee School of Engineering, Milwaukee, Wis., E. L. Weidner

Minnesota, University of, Minneapolis, Minn., J. H. Kuhlman

Northwestern University, Evanston, Ill., A. B. Brouwell

Purdue University, Lafayette, Ind., J. H. Bowman

Rose Polytechnic Institute, Terre Haute, Ind., C. C. Knipmeyer

Wisconsin, University of, Madison, Wis., R. R. Benedict

Not Represented

Lewis Institute, Chicago, Ill.

Notre Dame, University of, Notre Dame, Ind.

Student Branch Chairmen and Alternates

Armour Institute of Technology, Chicago, Ill., A. F. Veras

Detroit, University of, Detroit, Mich., John C. Price

Illinois, University of, Urbana, Ill., Robert M. Sinks

Iowa State College, Ames, Iowa, Richard P. Percy

Iowa, University of, Iowa City, Iowa, Francis L. Ohmer

Marquette University, Milwaukee, Wis., Joseph A. Morley

Michigan College of Mining and Technology, Houghton, Mich., G. M. Myron

Michigan State College, East Lansing, Mich., R. F. Schulte

Michigan, University of, Ann Arbor, Mich., W. R. Powers

Milwaukee School of Engineering, Milwaukee, Wis., R. J. Ungrodt

Minnesota, University of, Minneapolis, Minn., Robert MacDonald

Northwestern University, Evanston, Ill., R. J. Malone

Notre Dame, University of, Notre Dame, Ind., J. A. Varga

Purdue University, Lafayette, Ind., J. E. Nitsche

Rose Polytechnic Institute, Terre Haute, Ind., Willard Louthen

Wisconsin, University of, Madison, Wis., L. A. Burton

Not Represented

Lewis Institute, Chicago, Ill.

Others of the total of 40 persons attending the conference included President F. M. Farmer, Vice-President A. H. Lovell, National Secretary H. H. Henline, District Secretary A. G. Dewars, Secretary M. S. Coover of the AIEE committee on Sections, and Editor G. R. Henninger. Counselor B. S. Willis of Iowa State College presided.

District Executive Committee Meeting

At the meeting of the District executive committee Friday afternoon, September 29, K. A. Auty, Chicago, Ill., was unanimously re-elected District treasurer, and T. G. LeClair, Chicago, selected again as District delegate on the national nominating committee of the Institute. K. L. Hansen, Milwaukee, Wis., was nominated for vice-president of the Institute representing District 5, for the two-year term beginning August 1, 1940.

By action of the executive committee, the following will constitute the District coordinating committee for the year ending August 1, 1940:

A. H. Lovell, Michigan, vice-president
A. G. Dewars, Minnesota, secretary
B. S. Willis, Iowa, chairman of committee on student activities
J. J. Shoemaker, Michigan, vice-chairman, AIEE membership committee
A. J. Krupy, Chicago
H. W. Anderson, Iowa
I. B. Garthus, Minnesota
H. T. Kubiak, Madison

The advantages of setting up a separate committee to encourage transfers to higher grades of membership, as opposed to the practice employed by many Sections of delegating that responsibility to the membership committee were discussed by the committee. Although no action was taken, opinion seemed to favor the idea of a separate committee. The matter was regarded as one for local action by Sections, rather than for executive committee ruling.

The question of possible increase in the time interval allowed for transfer from Enrolled Student to Associate without payment of entrance fee was also discussed by the committee. National Secretary Henline explained that at one time the period was one and a half years after graduation, but pointed out that the percentage of transfers under that plan was 35 per cent, as compared to from 50 to 60 per cent under the present plan. A change in the Constitution would be necessary to alter the present plan, he said. No action was taken. Official attendants at the meeting included the following:

Great Lakes District, A. H. Lovell, vice-president; A. G. Dewars, secretary
AIEE Membership Committee, J. J. Shoemaker, District vice-chairman
Central Indiana Section, R. A. Scholl, secretary
Chicago Section, A. J. Krupy, chairman; F. V. Smith, secretary
Fort Wayne Section, F. H. Fleischer, chairman; C. R. Atkinson, secretary
Iowa Section, H. W. Anderson, chairman
Madison Section, H. J. Kubiak, secretary
Michigan Section, W. G. Knickerbocker, chairman
Milwaukee Section, L. T. Rosenberg, chairman
Minnesota Section, I. B. Garthus, chairman; K. J. Mertz, secretary
Urbana Section, G. H. Fett, chairman; C. A. Schille, secretary

President Farmer, National Secretary Henline, and Editor G. R. Henninger also attended.

Record of Attendance at Great Lakes District Meetings

Minneapolis, Minn.	September 1939	230
Lafayette, Ind.	October 1935	437
Milwaukee, Wis.	March 1932	552
Chicago, Ill.	December 1929	600
Chicago, Ill.	November 1927	900
Madison, Wis.	May 1926	180

Future AIEE Meetings

Winter Convention
New York, N. Y., January 22–26, 1940

Summer Convention
Swampscott, Mass., June 24–28, 1940

Pacific Coast Convention
Place and date to be announced

Middle Eastern District Holds Tenth General Meeting at Scranton

SCRANTON, center of the northeastern Pennsylvania anthracite region, was the scene of the tenth general meeting to be held by the Middle Eastern District. This was the second such meeting to be sponsored by the Lehigh Valley Section, another having been held in Bethlehem, Pa., in April 1927.

C. T. Sinclair of Pittsburgh, Institute vice-president for the Middle Eastern District, in speaking before the opening general session called attention to the fact that the Middle Eastern District embraces a strip of territory extending eastward from the Indiana boundary to the Atlantic coast and embracing the states of Ohio, West Virginia, Pennsylvania, Maryland, Delaware, and New Jersey with the exception of territory within the circle of 50-mile radius comprising the New York City District. He called attention also to the relatively scattered nature of the Lehigh Valley Section territory, the members of which are distributed among some 34 towns and cities ranging in population from 167 to 143,400, 16 of more than 12,000 and averaging about 51,000, 18 of less than 12,000 and averaging about 3,200. He credited the Lehigh Valley Section as being the first such "area" Section to hold Section meetings in rotation in the several larger cities of its territory, emphasizing that the Section over a period of years had carried on this program with notable success. Chairman E. F. DeTurk of the general committee presided at the opening session, and a representative of Mayor Fred Huester of Scranton was quite generous in proffering the city's keys and other facilities.

The total registered attendance of 313 at the Scranton meeting compares not unfavorably with the over-all average of 380 for the preceding nine meetings held by the District. In terms of the total registration, the attendance at sessions was relatively low, ranging from 30 to 100 and averaging just about 50. These figures undoubtedly reflect the fact that inspection trips were offered during session hours and the further fact that there were no student technical sessions. The total student registration was more or less normal, but aside from those who came to attend the District conference of Student Branch officers, the students came primarily to attend the testimonial luncheon given Thursday noon at the Hotel Casey in honor of Past-President Charles F. Scott, founder of AIEE Student Branch activities. The student group also participated in inspection trips, but did not to any appreciable extent attend the technical sessions.

Supplementing the technical sessions, generous inspection-trip facilities were offered by the Marvine anthracite coal mines of the Hudson Coal Company, the headquarters building of the International Correspondence Schools, the Wallenpaupack hydroelectric plant of the Pennsylvania Power and Light Company at Hawley, the Hazard insulated-wire works of the Okonite Company at Wilkes-Barre, and the Stanton steam plant jointly owned and operated by the Scranton Electric Company and the Pennsylvania Power and Light Company. The coal mines drew by far the largest number of visitors.

The big feature of the non-technical part of the program turned out to be the testimonial luncheon in honor of Doctor Scott. According to Chairman A. S. Mickley of the Lehigh University Student Branch, the day, October 12, was the anniversary date of the founding of the initial Student Branch at Lehigh University in 1902. An outline of Doctor Scott's early educational background was given by Dean W. M. Young of Ohio University, and Doctor Scott's professional career and activities were traced by Professor F. C. Caldwell of Ohio State University. In responding, Doctor Scott effectively emphasized to his listeners, among which were many students, that there is in effect just as much challenge and opportunity in the future before the young men of today as there was in the future before the young men of the past, and that individual initiative is just as valuable now as it ever was. He urged his listeners to look forward rather than to spend too much time looking backward, stating that "experience of the past is of value and worthy of recognition only in so far as it contributes to our present and future development."

A stag smoker held Thursday evening, October 12, drew an attendance of about 100. The program was a combination of a burlesque of an old-time frontier gaming casino and an auction sale wherein the participants were able to use their stage-money winnings for the "purchase" of prizes.

The relatively few women registered were generously entertained. For them there was a luncheon at the Scranton Club, an inspection trip to the International Correspondence School where tea was served, and an evening entertainment at the Jermyn Hotel, all on Wednesday, and on Thursday a bridge-luncheon at the Scranton Country Club.

The closing feature of the entertainment program was the informal dinner and dance that drew 96 to the Hotel Casey Thursday evening. Following the dinner and preceding the dance, an address on "Business and World Politics," was given by President Raoul E. Desvernine of the Crucible Steel Company of America, New York. The speaker sought to dispel the erroneous popular belief that "business men want war," asserting strongly that "just the contrary is true, because business as a whole has recognized and has had occasion to remember that new wars bring new regimentation and new controls for business and industry that never are wholly withdrawn afterward." Mr. Desvernine emphasized further that "business has its responsibilities to government and government has its responsibilities to business. The latter are just as imperative as the former if we are to be prepared to meet the exigencies of the moment and if we are to justify the efficiency of political and industrial democracy as a practical way of life in the face of a world challenge."

District Executive Committee Meets

With 10 out of 13 Sections represented, the District executive committee held a busy all-afternoon session October 11. District Vice-Chairman M. B. Wyman of the national membership committee reported more than 180 new members for the District since May of this year, and commented upon proposals to improve the scope and character of membership activities. There ensued an excellent example of the purpose for which such meetings are held—a generous exchange and constructive discussion of various ideas from and experiences of the different Sections. There was an extended discussion of the relative merits of the area Section plan such as that followed by the Lehigh Valley Section with rotated meetings, as against the plan of Section subdivision such as represented by the creation of the Mansfield Section from within the Cleveland Section territory. Opinions differed.

The matter of prize-paper competition within the District was reported upon by Professor A. G. Ennis of Washington, D. C., chairman of the District prize awards committee: So far this year two student papers and five other papers have been submitted. By action of the executive committee, the prize awards committee personnel will remain unchanged until February 15, 1940, after all the current year's papers are in, at which time a committee for the following year will be named. Present committee personnel:

A. G. Ennis, Washington, D. C.
F. E. Harrell, Cleveland
W. B. Morton, Philadelphia
E. W. Oesterreich, Pittsburgh
B. Van Ness, Jr., Baltimore

By action of the executive committee, the personnel of the District co-ordinating

Analysis of Registration at Scranton

Membership 8/1/39	Sections	Members	Enrolled Students	Men Guests	Women Guests	Totals
75	Akron	2	4	2	...	8
180	Cincinnati	4	...	...	...	4
298	Cleveland	6	...	...	...	6
95	Columbus	6	4	...	...	10
65	Erie	3	...	...	2	5
191	Lehigh Valley	61	12	22	11	106
224	Maryland	8	6	1	...	15
610	Philadelphia	21	6	16	3	46
517	Pittsburgh	21	5	2	3	31
86	Sharon	2	...	...	...	2
78	Toledo	1	1	1	...	3
332	Washington	3	1	1	...	5
	Non-Section Territory	...	1	1	...	2
		138	40	46	19	243
	From Outside District 2					
126	Central Indiana	...	3	3	...	6
733	Chicago	...	1	...	...	1
265	Connecticut	1	...	...	...	1
51	Ithaca	3	1	1	3	8
3,355	New York	21	...	7	4	32
178	Pittsfield	6	...	1	...	7
91	Providence	1	...	...	...	1
403	Schenectady	8	...	2	2	12
58	Worcester	1	...	...	1	2
		41	5	14	10	70
Totals		179	45	60	29	313

committee for the forthcoming year will be:

C. T. Sinclair, Pittsburgh, vice-president
W. J. Lyman, Pittsburgh, District secretary
L. R. Culver, Cincinnati, chairman of committee on student activities
R. W. Prince, Washington
S. S. Seyfert, Lehigh Valley
V. G. Rettig, Cincinnati
M. S. Schneider, Cincinnati

To form the District meeting committee, the foregoing list will be augmented by:

A. C. Burroway, Cincinnati
E. S. Fields, Cincinnati

For the dates of the District meeting scheduled for 1940 in Cincinnati, the Cincinnati Section representatives recommended October 9–11 as first choice and November 6–8 as second choice (the Student Branch counselors subsequently took action favoring the earlier date). Final decision was left to the District meeting committee.

A strong bid for the holding of the 1941 AIEE winter convention in Philadelphia was made by the representatives of the Philadelphia Section, with the support of the District's past vice-president, I. Melville Stein. After considering information as to the adequacy and suitability of facilities for hotel accommodations, meeting rooms, technical inspection trips, entertainment activities, and after reviewing the success of the 1924 winter convention as held in Philadelphia, the executive committee took unanimous action endorsing the proposal.

There was some discussion of the proposed model law for the registration of engineers, and suggestions for vice-presidential visits to Sections and Branches. Past-Vice-President I. Melville Stein was selected as Middle Eastern District delegate to the national nominating committee meeting that probably will be held during the forthcoming winter convention.

Official attendants at the executive committee meeting were as follows:

Middle Eastern District, C. T. Sinclair, vice-president; W. J. Lyman, secretary

AIEE membership committee, M. B. Wyman, vice-chairman

Akron Section, T. F. Brandt, chairman

Cincinnati Section, M. S. Schneider, chairman; V. G. Rettig, secretary

Cleveland Section, H. J. Dible, chairman; J. C. Strasbourger, secretary

Columbus Section, not represented

Erie Section, W. D. Bearce, secretary; J. D. Heibel, alternate for chairman

Lehigh Valley Section, J. E. Treweek, secretary

Mansfield Section, not represented

Maryland Section, H. A. Frey, chairman

Philadelphia Section, E. P. Yerkes, chairman; W. B. Morton, secretary

Pittsburgh Section, E. W. Oesterreich, chairman

Sharon Section, not represented

Toledo Section, J. S. Sawvel, chairman

Washington Section, A. G. Ennis, alternate for chairman

Others present included Past-Vice-President I. Melville Stein, Philadelphia, Pa., President F. M. Farmer, and Editor G. R. Henninger, New York, N. Y.

Student Branch Counselors Confer

Counselors of the Student Branches of the Middle Eastern District held an all-morning session at Scranton, Thursday, October 12. This group selected Professor L. R. Culver of Cincinnati to serve for the ensuing year as chairman of the District committee on student activities. In accordance with District custom, the retiring chairman, Professor E. E. Kimberly of Columbus was selected to serve for the same period as secretary, taking the place of the retiring secretary, Professor A. G. Ennis of Washington. The group also decided to hold the 1940 District conferences of Branch counselors and student officers in conjunction with the District meeting scheduled to be held in Cincinnati, probably in October.

A lengthy discussion and exchange of experiences incidental to the problem of developing student papers led to the adoption of a proposal endorsing the sentiments expressed at the 1939 summer convention conference, to the effect that a suitable standard award be adopted by the Institute in lieu of the present system of cash prizes for student papers. General sentiment was strongly to the effect that a medal, plaque, or other suitable trophy would be of much more lasting interest and value than any feasible cash prize which at best soon is spent and forgotten. Several problems of a local nature received attention also. Attending were the following official representatives:

Student Branch Counselors and Alternates

Akron, University of, Akron, Ohio, J. T. Walther

Bucknell University, Lewisburg, Pa., J. B. Miller

Case School of Applied Science, Cleveland, Ohio, J. R. Martin

Cincinnati, University of, Cincinnati, Ohio, L. R. Culver

Drexel Institute of Technology, Philadelphia, Pa., E. O. Lange

George Washington University, Washington, D. C., A. G. Ennis

Johns Hopkins University, The, Baltimore, Md., W. B. Kouwenhoven

Lafayette College, Easton, Pa., F. W. Smith

Lehigh University, Bethlehem, Pa., W. H. Formhals

Maryland, University of, College Park, Md., L. J. Hodgins

Ohio Northern University, Ada, Ohio, D. S. Pearson

Ohio State University, Columbus, Ohio, E. E. Kimberly

Ohio University, Athens, Ohio, W. M. Young

Pennsylvania State College, State College, Pa., P. X. Rice

Pennsylvania, University of, Philadelphia, Pa., Irven Travis

Pittsburgh, University of, Pittsburgh, Pa., H. E. Dyche

Princeton University, Princeton, N. J., A. E. Vivell

Swarthmore College, Swarthmore, Pa., J. D. McCrumm

Villanova College, Villanova, Pa., H. S. Bueche

West Virginia University, Morgantown, W. Va., A. H. Forman

Not Represented

Catholic University of America, Washington, D. C.

Carnegie Institute of Technology, Pittsburgh, Pa.

Branch Officers Hold Conference

Paralleling the conference of Student Branch counselors, the Branch officers met for the discussion and exchange of experiences concerning various questions relating to branch activities.

A suggestion for securing better attendance at Branch meetings was presented as the practice of the Branches at Carnegie Institute of Technology and Case School of Applied Science, where meetings are held in connection with weekly seminar courses at which attendance is compulsory for members of the junior and senior classes. A similar seminar is held at most of the larger engineering schools. This procedure was questioned by some, however, and was not regarded as generally practicable.

Copies of the *Case AIEE News Sheet*, Branch publication, were distributed and the suggestion made that the paper be developed into a joint publication for all Student Branches in the District, to be printed at Case. It was decided that Branch Chairman Swarthout of Case should investigate possibilities and notify the various Branches, and if possible, the plan should be undertaken.

Record of Attendance at Middle Eastern District Meetings

Scranton, Pa.	October 1939	313
Akron, Ohio	October 1937	464
Baltimore, Md.	October 1932	240
Pittsburgh, Pa.	April 1931	500
Philadelphia, Pa.	October 1930	500
Cincinnati, Ohio	March 1929	270
Baltimore, Md.	April 1928	400
Bethlehem, Pa.	April 1927	400
Cleveland, Ohio	March 1926	430
Washington, D. C.	January 1925	212

Attending this conference were the following official representatives:

Student Branch Chairmen and Alternates

Akron, University of, Akron, Ohio, M. A. Yakubik

Bucknell University, Lewisburg, Pa., H. D. Gulnac

Carnegie Institute of Technology, Pittsburgh, Pa., F. S. Adkins

Case School of Applied Science, Cleveland, O., D. K. Swarthout

George Washington University, Washington, D. C., C. G. Kurz

Johns Hopkins University, The, Baltimore, Md., F. H. Kohlhoff

Lafayette College, Easton, Pa., W. M. Piatt

Lehigh University, Bethlehem, Pa., A. S. Mickley

Maryland, University of, College Park, Md., W. H. Watkins

Ohio Northern University, Ada, Ohio, Richard Papenhausen

Ohio State University, Columbus, Ohio, L. R. Kempton

Ohio University, Athens, Ohio, E. C. Barnes

Pennsylvania State College, State College, Pa., H. R. Lloyd

Pennsylvania, University of Philadelphia, Pa., Ernest Boghosian

Pittsburgh, University of, Pittsburgh, Pa., R. A. Warren

Swarthmore College, Swarthmore, Pa., J. W. Kalb

Villanova College, Villanova, Pa., W. E. Kelly

West Virginia University, Morgantown, W. Va., D. T. Worrell

Not Represented

Catholic University of America, Washington, D. C.

Cincinnati, University of, Cincinnati, Ohio

Drexel Institute of Technology, Philadelphia, Pa.

Princeton University, Princeton, N. J.

Others present, in addition to Mr. Henline, were President Farmer, Doctor Charles F. Scott, and Retiring-Chairman E. E. Kimberly of the District committee on student activities.

There were no student technical sessions held in connection with this District meeting although a good many students registered for attendance at the Charles F. Scott testimonial luncheon and for registration in the technical inspection trips.

Nomination of AIEE Officers for 1940 Election; Members' Suggestions Invited Until December 15

FOR the nomination of national officers to be voted upon in the spring of 1940, the AIEE national nominating committee will meet during the winter convention, January 22–26, 1940. The officers to be elected are: a president, a national treasurer, three directors, and five vice-presidents, one from each of the odd-numbered geographical Districts. Fellows only are eligible for the office of president, and Members and Fellows for the offices of vice-president, director, and national treasurer.

To guide this committee in performing its constituted task, suggestions from the membership are, of course, highly desirable. To be available for the consideration of the committee, all such suggestions must be received by the secretary of the committee at Institute headquarters, not later than December 15, 1939.

In accordance with the provisions in the constitution and bylaws, as amended during 1935 and quoted in the following paragraphs, actions relative to the organization of the national nominating committee are now under way.

Constitution

28. There shall be constituted each year a national nominating committee consisting of one representative of each geographical district, elected by its executive committee, and other members chosen by and from the board of directors not exceeding in number the number of geographical districts; all to be selected when and as provided in the bylaws. The national secretary of the Institute shall be the secretary of the national nominating committee, without voting power.

29. The executive committee of each geographical district shall act as a nominating committee of the candidate for election as vice-president of that district, or for filling a vacancy in such office for an unexpired term, whenever a vacancy occurs.

30. The national nominating committee shall receive such suggestions and proposals as any member or group of members may desire to offer, such suggestions being sent to the secretary of the committee.

The national nominating committee shall name on or before January 31 of each year, one or more candidates for president, national treasurer, and the proper number of directors, and shall include in its ticket such candidates for vice-presidents as have been named by the nominating committees of the respective geographical districts, if received by the national nominating committee when and as provided in the bylaws; otherwise the national nominating committee shall nominate one or more candidates for vice-president(s) from the district(s) concerned.

Bylaws

SEC. 22. During September of each year, the secretary of the national nominating committee shall notify the chairman of the executive committee of each geographical district that by December 15 of that year the executive committee of each district must select a member of that district to serve as a member of the national nominating committee and shall, by December 15, notify the secretary of the national nominating committee of the name of the member selected.

During September of each year, the secretary of the national nominating committee shall notify the chairman of the executive committee of each geographical district in which there is or will be during the year a vacancy in the office of vice-president, that by December 15 of that year a nomination for a vice-president from that district, made by the district executive committee, must be in the hands of the secretary of the national nominating committee.

Between October 1 and December 15 of each year, the board of directors shall choose 5 of its members to serve on the national nominating committee and shall notify the secretary of that committee of the names so selected, and shall also notify the 5 members selected.

The secretary of the national nominating committee shall give the 15 members so selected not less than 10 days' notice of the first meeting of the committee, which shall be held not later than January 31. At this meeting, the committee shall elect a chairman and shall proceed to make up a ticket of nominees for the offices to be filled at the next election. All suggestions to be considered by the national nominating committee must be received by the secretary of the committee by December 15. The nominations as made by the national nominating committee shall be published in the March issue of ELECTRICAL ENGINEERING (Journal of AIEE), or otherwise mailed to the Institute membership not later than the first week in March.

INDEPENDENT NOMINATIONS

Independent nominations may be made in accordance with provisions in Section 31 of the constitution and Section 23 of the bylaws, which are quoted below:

Constitution

31. Independent nominations may be made by a petition of twenty-five (25) or more members sent to the national secretary when and as provided in the by-laws; such petitions for the nomination of vice-presidents shall be signed only by members within the district concerned.

Bylaws

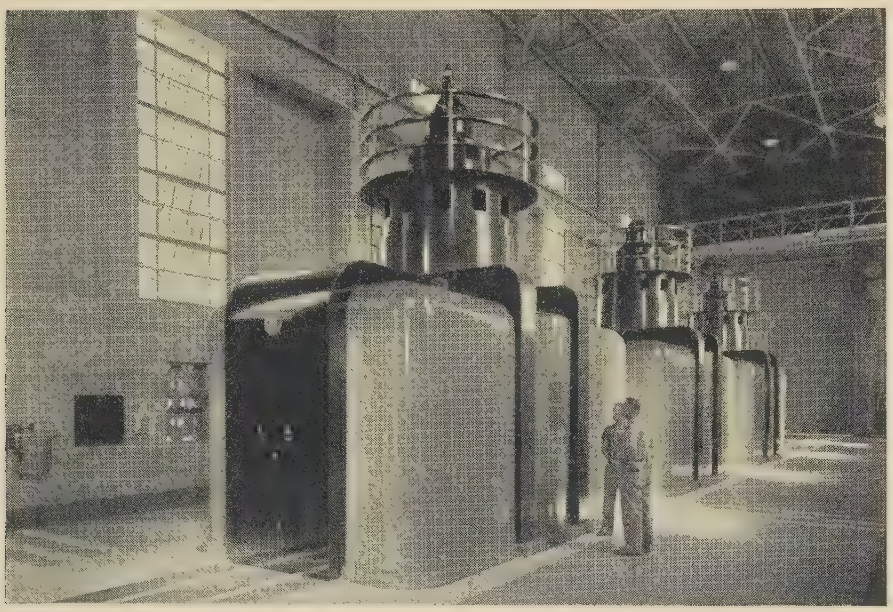
SEC. 23. Petitions proposing the names of candidates as independent nominations for the various offices to be filled at the ensuing election, in accordance with Article VI, Section 31 (constitution), must be received by the secretary of the national nominating committee not later than March 25th of each year, to be placed before that committee for the inclusion in the ballot of such candidates as are eligible.

On the ballot prepared by the national nominating committee in accordance with Article VI of the constitution and sent by the national secretary to all qualified voters during the first week in April of each year, the names of the candidates shall be grouped alphabetically under the name of the office for which each is a candidate.

(*Signed*) H. H. HENLINE,
National Secretary

November 1, 1939

Pump Motors at Eagle Mountain Ready for Service



SYNCHRONOUS pumping motors, each of which delivers 12,500 horsepower at 450 rpm to the vertical pumps, have been installed in the Eagle Mountain and Hayfield pumping stations of the Colorado River Aqueduct. Shown here are the three motors at the Eagle Mountain station, which, with their three duplicates at Hayfield, are said to be the largest pumping motors in the world. They were made by Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. The motors are started directly across 6,900-volt lines fed through transformers from the 230-kv line built solely to carry power from Boulder Dam for aqueduct pumping. Delivery of water to coast cities is expected early in 1940 by the Colorado River project, which includes a diversion and power dam, 150 miles below Boulder Dam, five pumping stations with an aggregate lift of 1,634 feet, and 242 miles of aqueduct. (For Aqueduct details see TRANS., March 1939, pp. 112–23.)

Hoover Medal for 1939 Awarded to Gano Dunn

The Hoover Medal "awarded by engineers to a fellow engineer for distinguished public service" by a joint engineering societies board will be given for 1939 to Gano Dunn (A'91, F'12) president of the J. G. White Engineering Corporation, New York, N. Y., and past-president and Edison Medalist of the AIEE. The award will be formally made during the Institute's coming winter convention, in New York, N. Y., January 22–26, 1940. A biographical sketch of Doctor Dunn appears elsewhere in this issue.

Instituted in 1929 by gift of Conrad N.

Lauer of Philadelphia, past-president of The American Society of Mechanical Engineers, the Hoover Medal has been awarded four times, first to former President Herbert Hoover (HM'29) whose civic and humanitarian achievements it was established to commemorate; to Ambrose Swasey (HM'28) founder of the Engineering Foundation; and to John Frank Stevens, chief engineer of the Panama Canal. Members of the board of award which selected Doctor Dunn, and the societies they represent, were: for the American Society of Civil Engineers, Ralph Budd, A. S. Crane (A'04, M'13), the late Thaddeus Merriman (died September 26, 1939); for the American Institute of Mining and Metallurgical Engineers, C. H. Crane, J. V. W. Reynders, Scott Turner; for The American Society of Mechanical Engineers, W. H. Kenerson, C. N. Lauer, S. F. Voorhees; for the AIEE, H. H. Barnes, Jr. (A'00, F'13), A. W. Berresford (A'94, F'14, past-president), William McClellan (A'04 F'12, past-president).

ECPD Selects Officers and Committees

At its seventh annual meeting held October 20, 1939, the Engineers' Council for Professional Development re-elected J. P. H. Perry, vice-president, Turner Construction Company, New York, N. Y., as chairman, and R. E. Doherty (A'16, F'39) president, Carnegie Institute of Technology, Pittsburgh, Pa., as vice-chairman. C. E. Davies, secretary, The American Society of Mechanical Engineers, was elected secretary of ECPD, and G. T. Seabury, secretary, American Society of Civil Engineers, assistant secretary. United Engineering Trustees, Inc., was reappointed treasurer of ECPD. Chairmen of three committees were reappointed as follows: R. L. Sackett, student selection and guidance; O. W. Eshbach (A'17, F'37) professional training; C. F. Scott (A'92, F'25, HM'29) professional recognition. A. A. Potter was appointed chairman of the committee on engineering schools, and J. C. Arnell (A'28) was reappointed chairman of the junior committee on professional training.

Upon recommendation of the retiring executive committee, the following were reappointed to the executive committee for the ensuing year: E. R. Needles, representing ASCE; G. B. Waterhouse, representing the American Institute of Mining and Metallurgical Engineers; R. E. Doherty (A'16, F'39) representing the Society for the Promotion of Engineering Education. Members newly elected to the executive committee were: A. R. Stevenson, Jr. (A'20, F'37) representing ASME (alternate during 1938–39); J. F. Fairman (A'20, F'35) representing AIEE; B. F. Dodge, representing the American Institute of Chemical Engineers; C. F. Scott (A'92, F'25, HM'29) representing the National Council of State Boards of Engineering Examiners.

Appointments of the following representatives by the various societies for the three-year term 1939–42 were announced: ASCE, F. E. Winsor (reappointment); AIME, W. B. Plank (reappointment); ASME, R. L. Sackett; AIEE, O. W. Eshbach; SPEE, R. A. Seaton (reappointment); AIChE, C. M. A. Stine; NCSBEE, C. F. Scott.

Dean Sackett's committee on student selection and guidance presented a revised draft of the booklet "Engineering—A Career, a Culture," on which work has been under way for the past year or two. The Council accepted the draft; voted unanimously to change the title to "Engineering as a Career," and to submit it for review and criticism to the entire personnel of the governing bodies of the societies of which ECPD is a joint agency.

Doctor Compton's committee on engineering schools reported that, including action at this meeting of the Council, some 687 curricula of 140 degree-granting engineering institutions have been acted upon or are under consideration. Out of 155 such institutions in the United States, 150-odd have asked for inspection. As of October 1938, 678 curricula of 136 schools had been reviewed. A detailed and up-to-date list of engineering curricula accredited by ECPD is expected to be available for inclusion in the December issue of ELECTRICAL ENGINEERING.

The seventh annual dinner of ECPD was held Friday evening, October 29, at the Engineers' Club, New York. Chairman Perry presided and in his opening remarks emphasized the necessity of a "long-range view" toward the development of ECPD, pointing out that such an attitude was particularly significant in trying to develop a program of community interest among seven large participating bodies. The first speaker, A. A. Potter, dean of engineering, Purdue University, incoming chairman of the committee on engineering schools, reviewed the work of the committee, and paid special tribute to the retiring chairman, Doctor Karl T. Compton (F'31) president, Massachusetts Institute of Technology.

D. S. Bridgman of the American Telephone and Telegraph Company outlined the employment and personnel policy and experience of that company, with especial regard to the assimilation of engineering and other graduates. He declared that "observation shows all classes of graduates today to be distinctly better and more broadly trained than was the case with the average of ten years ago."

Doctor E. S. Burdell, director, Cooper Union for the Advancement of Arts and Sciences, New York, spoke on "the development of professional competency" and the place of the engineering school in bringing it about, and stated that in his opinion it was the responsibility of the schools to offer studies assuring broad development. He said that Cooper Union intends to parallel its technical courses for the upper classes with general and philosophical studies of similar rank.

Speaking on the subject "What Becomes of the Engineering Graduate?" R. C. Muir, vice-president in charge of engineering, General Electric Company, Schenectady, N. Y., declared that "engineers not only have, but were fairly successfully serving a definite mission to society," which he defined as making a contribution to the improvement of human life. He also said that the experience of his company showed improvement in the quality of engineering graduates over a 20-year period. He pointed out that technical graduates found their way, according to their own bent, into all activities of the company. Less than ten per cent of engineering graduates, he said, remain in fields of basic technical development; the others are distributed among other operations of equal importance. He expressed the opinion that educators "should give more attention to the 90 per cent."

J. V. Davies Dies; Tunnel Engineer

John Vipond Davies, consulting civil engineer associated with many well-known tunnel projects in the United States and other countries, died October 3, 1939. He was born at Swansea, South Wales, October 13, 1862, educated at Wesleyan College, Taunton, Eng., and the University of London, and engaged in engineering work in steel and mining in England before coming to the United States in 1889. He was for many years associated with the consulting firm of Jacobs and Davies, New York, N. Y., of which he became president in 1917. His engineering activities included railway, subway, and dam construction, in addition to tunnel projects, among the latter being the Hudson River tunnels of the Hudson and Manhattan Railroad, aqueduct tunnels in Mexico, the Moffat tunnel in the Rocky Mountains, and various tunnels under the Hudson and East Rivers for utilities in the New York City area.

He received the Telford Gold Medal of the Institution of Civil Engineers of Great Britain, the Norman Gold Medal and other awards of the American Society of Civil Engineers; was a member of both those and several other engineering societies, and past-president of the United Engineering Societies.

Future Meetings of Other Societies

American Association for the Advancement of Science. Winter meeting, December 27, 1939–January 2, 1940, Columbus, Ohio.

American Institute of Mining and Metallurgical Engineers. 152d annual meeting, February 12–15, 1940, New York, N. Y.

American Physical Society. 230th meeting, December 1–2, Chicago, Ill.

231st meeting, December.

Annual meeting (232d), December 28–30, Columbus, Ohio.

233d meeting, February 22–24, 1940, New York, N. Y.

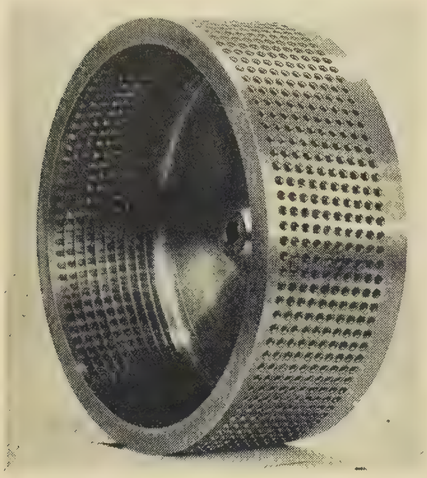
American Society of Civil Engineers. Annual meeting, January 17–20, 1940, New York, N. Y.

American Society of Heating and Ventilating Engineers. 46th annual meeting, January 1940, Cleveland, Ohio.

American Society of Mechanical Engineers. Annual meeting, December 4–8, Philadelphia, Pa.

Société Française des Électriciens. Television meeting, November, Paris, France.

High-Speed Camera to Photograph Electric Arcs



A CAMERA that will take pictures at the rate of 120,000 per second through 1,000 pinhole-sized apertures has been developed by W. K. Rankin, General Electric Company, Philadelphia, Pa. It was designed to photograph electric arcs, thus enabling engineers to study arc behavior in apparatus. Instead of glass lenses, with which reflection from the brilliancy of the arc caused distortion of the image, the camera has holes of 0.01-inch diameter through which light passes to the film. The holes, arranged in ten rows in such a way that no two are exactly opposite each other and no two come into photographic position at the same time, surround a metal drum. The film is placed inside the drum and is held in place by centrifugal force. The drum is revolved by a one-half-horsepower motor capable of 7,200 rpm. As it revolves, each hole passes a slot extending the width of the film, thus exposing an individual picture, nine millimeters square, and the 1,000 pictures which can be taken with a single film are made by one complete revolution. The illustrations show the camera-lens drum and photographs of an arc by the high-speed camera showing changes in arc intensity.

Current Items From American Engineering Council

War Means Changes in U. S. Economy

Although direct participation by the United States in hostilities engaging major European nations now appears remote, a realistic appraisal of the situation indicates that widespread changes directly affecting the American people are logically to be expected.

Two essential factors bearing upon this question are still unsettled. The first is the type of war that is to be fought in Europe—whether it will be an aggressive attempt to force a quick conclusion, or a blockade that will reduce land warfare to a stalemate and rely upon economic isolation to bring about a final settlement. The second consideration is the type of neutrality legislation that will eventually emerge from the debates of the American Congress, and the extent to which trading with actual belligerents will be permitted under its provisions. Each of these decisions will have its effect in modifying the impact of hostilities upon this country, but neither of them can nullify the basic truths that, so long as the war continues, (1) world consumption will be increased because of the wastes of war; (2) world production will be curtailed by the diversion of man-power from factories to armed forces; (3) international trading, particularly with neutral countries, will experience profound changes. As the principal industrial nation not now engaged in war, the United States cannot avoid being affected by these fundamentals.

Many experts discount expectations of an immediate boom in war orders. Pointing out that the pick-up in business that has been experienced since September 1 has been due less to orders from abroad than to domestic stocking-up against the contingency of price increases, they forecast, at the most, a rather gradual and selective volume of foreign purchases in this country during the near future. Eventually, assuming that such buying is legal under the revised neutrality law, it should attain a considerable volume, but its impact upon the American economy is not expected to be sudden.

Of equal importance to the industrialist is the effect of our own preparedness program. Initiated before the outbreak of hostilities in Europe but greatly stimulated thereby, orders relating to national defense from both the government and from private sources are already crowding several industries, notably shipbuilding, aviation, and heavy electrical equipment. As the program authorized by Congress continues to materialize in actual orders the effect upon industry will become more and more apparent.

Another important consideration is the fact that, for the duration of the war, neutral nations that have been buying goods from the belligerent countries will find it increasingly difficult to get deliveries of needed articles. Many will be forced to turn to other sources of supply, and the United States will inevitably receive much of this business.

The cumulative effect of these considerations is the inescapable conclusion that, if the war continues, this country will be called upon for a continually increasing volume of production. This, in turn, will build up payrolls and thus generate increased domestic consumption, adding still more to the demand for goods. How well are we equipped to meet this situation?

Basic factors in industrial production comprise land, capital, plants and equipment, raw materials, labor, power, and transportation. Of land and capital we have an abundance. Current studies indicate that we are now using our industrial equipment at somewhere between two-thirds and three-quarters of its nominal capacity, so that considerable expansion is possible without the necessity for any substantial construction program. The fact that an early peace would dissipate much of the prospective business volume will serve as an additional deterrent against an immediate boom in factory construction except, of course, in specific fields where demand will be concentrated.

As regards raw materials the situation is spotty. Those produced domestically, whether by mining or by agriculture, are generally available in abundance, but those procured from abroad may be limited by complications induced by the war and, specifically, by shortages in shipping. Here generalities are dangerous and each specific commodity must be considered in the light of circumstances. On the whole, however, the situation is not unduly discouraging.

Labor, power, and transportation were the bottlenecks of United States industry during the last World War. Whether history will repeat itself in this respect remains to be seen, although conditions have changed radically and, on the whole, for the better, during the intervening years. But the depression has been a poor preparation period for all three.

Shortages in skilled labor will undoubtedly develop in some lines before industrial production expands very far—in fact, aviation and shipbuilding are already experiencing discomfort in this respect. Although many industries have mechanized their operations to a considerable extent in the last 25 years and are less dependent upon specialized skills, and although even the extreme of American participation in hostilities is expected, according to present mobilization plans, to respect the needs of industry for specially qualified men, the labor problem has the most ominous aspect of any here considered.

The outlook for transportation is somewhat less serious. Broadly speaking the

railroads, which were tied up in knots during the last war, have retained undiminished their capacity for moving goods, and in the meantime an entire new supplement—highway transportation—has developed to serve as a relief valve. Already steps are being taken by the railroads to refurbish and supplement old equipment in anticipation of an increasing volume of traffic.

In considering the power situation two factors must be balanced. On the one hand reserve generating capacity within the utility industry is much higher than it was in 1914; on the other, industry is now much more dependent than it was then upon purchased electric power. An additional cushion is provided by the widespread existence of interconnections between different generating areas, permitting the exchange of power to meet diverse needs. During the last war the difficulty of obtaining coal in adequate quantities was a major source of trouble; now we have many mines that are either closed down entirely or operating much under capacity. This problem concerns both power and transportation, but it should be noted that now it takes only about $1^1/_2$ pounds of coal to produce a kilowatt-hour of electricity, as compared with approximately 4 pounds in 1914. In addition, the elimination of many scattered industrial power plants should do much to simplify the problem of delivering fuel where it is needed. Hydroelectric power is also available in much larger quantities, with much unused capacity available at the various Federal public works projects now approaching completion.

No attempt is made herein to discuss long-term effects of this prospective increase in business volume, nor to consider whether the United States will, in the long run, benefit or suffer from the economic changes that will result. If demands for goods develop in accordance with the conditions discussed above, it is inconceivable that they will not be met to a greater or lesser extent by American industry. But no one familiar with the economic consequences of the last war can fail to realize that any substantial expansion of this country's productive equipment will involve serious problems of readjustment when hostilities finally come to a close and belligerent Europe resumes peaceful production.

Strategic Minerals Sought

As the result of recommendations by the Army and Navy munitions board, the Department of the Interior now has engineering parties at work in seven states investigating possible sources of supply for minerals needed for national defense and not at present produced in sufficient quantities within the United States. Particular stress is being laid upon potential supplies of antimony, chromium, manganese, tin, and tungsten. The investigations are being carried on in Montana, Wyoming, Oregon, Washington, South Dakota, New Mexico, and Nevada.

President Roosevelt has issued a general request to owners of stocks of these and other important strategic minerals not to sell them to foreign purchasers but to hold them for possible use within this country.

Standards

Standards Committee to Study Voltages Below 100

A subcommittee of the standards committee has been organized to study standardization of voltages below 100. The committee at present has eight members under the chairmanship of Professor D. F. Miner of the Carnegie Institute of Technology. In order to obtain representation from all interested fields, it may become advisable to add one or two additional members. It is expected that this Subcommittee will co-ordinate its work with that of an American Standards Association committee to be organized at the suggestion of NEMA for making a similar study.

Voltages below 100 are used much more extensively than most of us realize and it is surprising that national standardization in this range has not been undertaken sooner, all the more so as the International Electrotechnical Commission has been working on an international standard for some years. Their publication No. 38 on "IEC Standard Voltages," recently issued, includes a tabulation of values below 100.

A preliminary survey has been made to obtain data on present practices in the following: central stations, signalling, railways and buses, arc devices and therapeutic, telephones, welding, lighting, portable tools and devices, electronics.

This preliminary survey indicates that there are now in use in the United States 42 well-established voltages in the range 1 to 100 volts. These fall into apparatus classes with preference for certain voltages for certain applications. Further study will be made of the data to determine whether some simplification and standardization is practicable. There appear to be very few existing standards at present even for specific types of apparatus. It may not be possible to adopt standard voltages applicable to all apparatus, but it will be useful to suggest standard values at least for specific apparatus classes, such as signaling, supervisory control, and electronic tubes.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or reject them entirely.

ALL letters submitted for consideration should be the original typewritten copy, double spaced. Any illustrations submitted should be in duplicate, one copy to be an inked drawing but without lettering, and the other to be lettered. Captions should be furnished for all illustrations.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

Why So Few Famous Engineers Today?

To the Editor:

In the presentation of answers to the question indicated in the above title in both Mr. Gannett's article in *Engineering News Record* and in ELECTRICAL ENGINEERING'S comments in the October 1939 issue, "famous engineers" rather than "great engineers" are considered. There is a fundamental difference here, and the terms must not be confused. Some of the requirements to make an engineer *famous* do not apply at all in making an engineer *great.* Such, for example, are "salesmanship," "showmanship," "luck," even outward "enthusiasm," although it is conceded that no man grows in his profession without that inward enthusiasm and love for his job which keep him forever at it. An engineer to become great must, above every other quality, possess great ability and great character; in fact these two terms include every other characteristic necessary.

I believe there are at the present time more great engineers than in any previous period in the history of the profession. And perhaps for this very reason there are not many famous in the sense of standing out in the headlines above their fellows and exciting popular imagination. Otherwise how can we account for the Hudson tunnels and bridges; Colorado canyon crossings and Boulder dams; Grand Coulees and the magnificent palaces of the air? Many of the modern engineering feats require the combined brains and skill of several great engineers. Technological progress can no longer depend on an Arthur Morgan or a General Goethals. Engineering projects and completed works have in 20 years become so numerous and so immense and exacting as to require the utmost in character and ability of trained and experienced men. By comparison the bridges of Eads and of the Roeblings and the circuits of Marconi and Pupin pale into virtual insignificance. And yet to engineering minds—even to lay minds—these have become so familiar that they no longer possess the glamor and interest which attached to the fewer accomplishments of possibly lesser minds of former years. Furthermore, the professional spirit and ethics of engineering today curb those elements of character which make for publicity and showmanship justly frowned upon even by the lay public. In short, among the many on the higher levels of ability rarely may one outshine in intelligence and skill. Great works are taken for granted while their designers and builders are of secondary interest or are entirely overlooked.

Literary connoisseurs 50 or 60 years of age are lamenting the absence today of such geniuses as graced the fields of literature in former years. They ask "Where is

there a Shakespeare or a Milton; an Emerson or a Hawthorne?" The conditions are similar to those in engineering, and the answers are in general identical. A misquotation of President Davis, Stevens Institute of Technology, appropriately sums up the situation in engineering: "Engineering itself may (has) become more famous than any of the great personalities" who have made it so.

Very truly yours,
A. A. Atkinson (A'07, M'27)

(Retired dean, college of applied science, Ohio University, Athens, Ohio)

To the Editor:

Mr. Farley Gannett's query as to the cause of the apparent dearth of individually outstanding engineers today as compared with the number of "giants (engineering) in those days" can be answered, in my opinion, as follows:

In the earlier days of engineering, during the 19th century and the first decade of the present century, there was less specialization in the engineering field than there is today, with the result that an individual engineer wrestled personally with all of the problems of an engineering project, both of theory and of practice, and hence he stood out over his relatively few fellow engineers. The individual engineer's work today is more highly specialized, is in cooperation with the work of many able fellow engineers, and hence, in general, he no longer towers above them, nor does he, as an individual, assume such a prominent position in the public (whether engineering or lay) eye.

To put it otherwise: Formerly we beheld an engineer and his assistants; today we are shown an engineer and his collaborators. The writer was fortunate enough to have had personal contact with some of the engineering giants of former years, but it is his belief that we have engineers now with us of equal ability, who are not so outstanding because there are a larger number of them.

Sincerely yours,
Mortimer Freund (A'07, M'12)

(Member of firm, Eadie, Freund, and Campbell, consulting engineers, New York, N. Y.)

A New Method of Determining Per Cent Harmonics

To the Editor:

The per cent harmonics in any type of wave is generally determined by the use of the harmonic analyzer or by subjecting the oscillogram of the wave to Fourier analysis. Quite often the harmonic analyzer is not available to the engineer and Fourier analysis leads to tedious efforts. However, in the case where the wave to be analyzed contains only three components or less: for example, fundamental, third, and fifth harmonics, or fundamental, second, and third harmonics, and so on, a method is available by which the per cent harmonics can be readily determined by the use of a voltmeter and ammeter. The following derivation will serve to illustrate the principle.

In general any type of current wave can be represented as:

$$i = \Sigma I_n \sin(n\omega t + \alpha_n) \tag{1}$$

where:

n = whole number indicating the order of the component.
I_n = maximum value of the wave component.
ω = $2\pi \times$ fundamental frequency.
α_n = phase angle of the component wave.

If this current flows through a fixed capacitor of zero power factor, the capacitor voltage becomes:

$$e_c = \frac{1}{c}\int idt$$

$$= -\sum \frac{I_n}{n\omega c}\cos(n\omega t + \alpha_n) \tag{2}$$

The effective value of this voltage is then,

$$E_{c_{eff}} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} e_c^2 dt}$$

$$= \frac{1}{\omega c}\sqrt{\frac{1}{2}\sum\left(\frac{I_n}{n}\right)^2} \tag{3}$$

Since the effective value of any current is defined as

$$I_{eff} = \sqrt{\frac{1}{2}\sum(I_n)^2} \tag{4}$$

equation 3 can be rewritten as:

$$E_{c_{eff}} = \frac{1}{\omega c}\sqrt{\frac{\sum\left(\frac{I_n}{n}\right)^2}{\Sigma(I_n)^2}}\cdot I_{eff} \tag{5}$$

$$\frac{\sum\left(\frac{I_n}{n}\right)^2}{\Sigma(I_n)^2} = \left\{\frac{\omega c \cdot E_{c\,eff}}{I_{eff}}\right\}^2 = F_c \tag{6}$$

where F_c is measurable.

In the same manner, when the current is made to flow through a pure inductance of constant value, the effective voltage across the inductance becomes:

$$E_{L_{eff}} = \omega L\sqrt{\frac{\Sigma(nI_n)^2}{\Sigma(I_n)^2}}\cdot I_{eff} \tag{7}$$

$$\frac{\Sigma(nI_n)^2}{\Sigma(I_n)^2} = \left\{\frac{E_{L_{eff}}}{\omega L \cdot I_{eff}}\right\}^2 = F_L \tag{8}$$

where F_L is measurable.

The component currents can now be placed in terms of the fundamental such that:

$$I_n = K_n I_f \tag{9}$$

where K_n is the per cent harmonic for the component in question. Substituting equation 9 in equations 6 and 8:

$$\frac{\sum\left(\frac{K_n}{n}\right)^2}{\Sigma(K_n)^2} = F_c \tag{10}$$

$$\frac{\Sigma(nK_n)^2}{\Sigma(K_n)^2} = F_L \tag{11}$$

In the case where the wave is composed of three components there will be just two unknowns, K_{n_1} and K_{n_2}, which are solvable by equations 10 and 11. The lower and higher components can be written respectively as:

$$(K_{n_1})^2 = \frac{(n_2^2 - 1)F_c + \left(1 - \frac{1}{n_2^2}\right)F_L + \left(\frac{1}{n_2^2} - n_2^2\right)}{(n_1^2 - n_2^2)F_c + \left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)F_L + \left(\frac{n_2^2}{n_1^2} - \frac{n_1^2}{n_2^2}\right)} \tag{12}$$

$$(K_{n_2})^2 = \frac{(n_1^2 - 1)F_c + \left(1 - \frac{1}{n_1^2}\right)F_L + \left(\frac{1}{n_1^2} - n_1^2\right)}{(n_2^2 - n_1^2)F_c + \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)F_L + \left(\frac{n_1^2}{n_2^2} - \frac{n_2^2}{n_1^2}\right)} \tag{13}$$

As an illustration when the wave consists of a fundamental, third and fifth harmonics, $n_1 = 3$ and $n_2 = 5$, and equations 12 and 13 reduce to

$$K_3 = \sqrt{\frac{24F_c + .96F_L - 24.96}{-16F_c - .0711F_L + 2.42}} \tag{14}$$

$$K_5 = \sqrt{\frac{8F_c + .999F_L - 8.99}{16F_c + .0711F_L - 2.42}} \tag{15}$$

In the case of a wave with only two components either equation 10 or equation 11 can be used. If equation 10 is used then the per cent harmonic becomes

$$K_n = \sqrt{\frac{F_c - 1}{\left(\frac{1}{n^2} - F_c\right)}} \tag{16}$$

Measurement of F_c and F_L

The values of F_c and F_L may be obtained by measuring separately the current, voltage, and the impedance of the capacitor and inductance at the fundamental frequency. They may also be obtained directly by the following scheme.

Measure the voltage $E_{c_{eff}}$ at a certain value of I_{eff}. Next impress a pure sine wave voltage $E_{c_{sine}}$ on the capacitor and adjust the voltage until the same I_{eff} is obtained. It is obvious from equation 5 or 6 that:

$$F_c = \left\{\frac{E_{c_{eff}}}{E_{c_{sine}}}\right\}^2 \tag{17}$$

In the same manner

$$F_L = \left\{\frac{E_{L_{eff}}}{E_{L_{sine}}}\right\}^2 \tag{18}$$

In conclusion some of the limitations of the method are listed. They are:

1. The method is applicable only to waves containing three components or less.
2. The order of the components present must be known.
3. For accurate results the power component of the two impedances must be small.

Provided these three conditions are satisfied the method outlined enables a rapid calculation of the per cent harmonics.

Very truly yours,
W. T. Thomson (A'37)

(Instructor in applied mechanics, Kansas State College of Agriculture and Applied Science, Manhattan, Kans.)

Personal Items

Gano Dunn (A'91, F'12) president, J. G. White Engineering Corporation, New York, N. Y., has been chosen to receive the Hoover Medal for 1939, joint engineering-society award, which will be presented at the AIEE winter convention, New York, N. Y., January 22–26, 1940. An account of the award appears elsewhere in this issue. Doctor Dunn was born October 18, 1870, in New York, N. Y., and received the degrees of bachelor of science (1889) from the College of the City of New York, electrical engineer (1891) from Columbia University, master of science (1897) from CCNY, and the honorary degrees of master of science (1914) and doctor of science (1938) from Columbia. Employed by Western Union Telegraph Company, New York, as night operator 1886–91, he entered the service of the Crocker-Wheeler Electric Manufacturing Company, Ampere, N. J., in 1891, and from 1898 to 1911 was vice-president and chief engineer. In 1911 he became vice-president of J. G. White and Company and upon the organization of the J. G. White Engineering Corporation in 1913 became its president, a position he has held ever since. From 1916 to 1918 he was a member of the War Department Nitrate Commission, and in 1918 chairman of a joint committee on submarine cables. He was also a member of the engineering committee of the Council of National Defense. In 1936 he represented the State Department at the World Power Conference. He is chairman of the visiting committee of the National Bureau of Standards, and a member of the Patent Office advisory committee, the President's committee on civil service improvement, the Science Advisory Board, and the business advisory board of the Department of Commerce. Since 1935 he has been president of Cooper Union for the Advancement of Science and Art, of which he was formerly a trustee, and he is a trustee of Barnard College and a former alumni trustee of Columbia University. He received the Townsend Harris Medal of the College of the City of New York in 1933 and the Edison Medal of the AIEE for 1937. He has served the AIEE as a manager, vice-president, president (1911–12), member of many committees, and representative on various organizations. He was president of the New York Electrical Society 1900–02, of the United Engineering Societies 1913–16, of the John Fritz Medal Board of Award 1914. He was first chairman of the Engineering Foundation, 1915–16, and chairman of the National Research Council 1923–28. He has been active in international scientific organizations, is honorary secretary for the United States of the Institution of Electrical Engineers, honorary member of the Association of Iron and Steel Engineers, member of the American Society of Civil Engineers, American Society of Mechanical Engineers, Institute of Radio Engineers, American Association for the Advancement of Science, and numerous other scientific societies, and the author of many papers on engineering subjects.

E. W. Allen (A'03, F'22) vice-president, General Electric Company, Schenectady, N. Y., has been appointed chairman of the Institute's Lamme Medal committee for 1939–40. He was appointed to the committee for the term 1938–41. Born in Buchanan, Va., November 9, 1879, he received the degree of bachelor of science in electrical engineering from Virginia Polytechnic Institute in 1900. He entered the testing course of General Electric at Schenectady in January 1901, and was assigned to the engineering department the latter part of the following year. In 1911 he became district engineer with headquarters at Chicago, Ill., and in 1913 was made assistant district manager in addition to his duties as engineer. He was in military service 1917–19, after which he returned to his position at Chicago. He was appointed manager of the company's engineering department at Schenectady in 1924, and vice-president in 1926. He has served on the Institute's education committee and as Institute representative on the United States national committee of the International Electrotechnical Commission.

D. C. Jackson, Jr. (A'23, F'30) has been appointed dean of the college of engineering at the University of Notre Dame, Notre Dame, Ind. Born August 3, 1895, at Madison, Wis., he received the degree of bachelor of arts in scientific studies at Harvard University in 1917 and the degrees of bachelor of science (1921) and master of science (1922) at Massachusetts Institute of Technology in the co-operative electrical-engineering course with General Electric Company. He served in the United States Army 1917–19 as an officer in the Coast Artillery. He was instructor in electrical engineering at the University of Missouri, Columbia, 1922–23 and assistant professor of electrical engineering in charge of electrical-engineering instruction, Trinity College, now Duke University, Durham, N. C., 1923–25. From 1925 to 1930 he was professor and head of the department of electrical engineering at the University of Louisville, Louisville, Ky., and from 1930 to February 1936 held the same position at the University of Kansas, Lawrence. He became director of Lewis Institute, Chicago, Ill., at the beginning of the academic year in 1935, continuing there until 1938. During recent months he has been working with his father, Doctor Dugald C. Jackson (A'87, F'12) on a survey of engineering education conducted by the Engineers' Council for Professional Development. Dean Jackson is a member of the American Society of Civil Engineers, American Society of Mechanical Engineers, and Society for Promotion of Engineering Education.

O. C. Spurling (A'03, M'10) has retired as engineer of plant, Western Electric Company, New York, N. Y. Born September 19, 1874, at St. George's, Bermuda, he was educated there and studied electrical engineering at Pratt Institute and the Chicago School of Electricity. He was employed by Western Electric in New York as a wireman's helper in 1893, and from 1896 to 1898 was engaged in testing for the company in Chicago, Ill., returning to New York as assistant to factory engineer. He was sent abroad in 1902 in charge of design and installation of plants and equipment in London, Eng., and Antwerp, Belgium. After his return in 1905 he assumed charge of building operations at the Hawthorne works of the company near Chicago. Since 1923 he has been engineer of plant, with headquarters in New York, directing construction of the company's factories at Kearny, N. J., and Point Breeze, Baltimore, Md., and other plant expansion. He is a member of The Institution of Electrical Engineers of Great Britain.

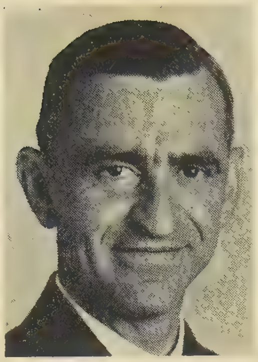
J. T. Graff (A'21, M'27) has been appointed assistant vice-president, operation, of the Chesapeake and Potomac Telephone Company, Washington, D. C., handling engineering, plant service, and costs matters. Born December 1, 1877, at Washington, D. C., he received the degree of mechanical engineer from Cornell University in 1900 and was employed by the Western Electric Company, New York, N. Y., the same year. In 1901 he was transferred to the New York and Pennsylvania Telephone and Telegraph Company, Binghamton, N. Y., as wire chief, and in 1902 was again transferred to the Chesapeake and Potomac Telephone Company of Baltimore City, Baltimore, Md. He became district plant supervisor in 1909 and division plant engineer in 1913. From 1917 to 1919 he was in military service, returning to the office of the general

GANO DUNN

D. C. JACKSON, JR.

E. W. ALLEN

H. F. HARVEY, JR.



RAYMOND BAILEY

J. T. GRAFF

plant manager of the Chesapeake and Potomac companies. He was appointed general plant supervisor in 1927, and chief engineer for Virginia in 1935, continuing in that position until his present appointment.

Raymond Bailey (A'17, M'26) assistant electrical engineer, Philadelphia Electric Company, Philadelphia, Pa., has been appointed chairman of the AIEE committee on power transmission and distribution for 1939–40. He has been a member of the committee since 1933, and was vice-chairman 1937–1939. Mr. Bailey was born in Philadelphia May 3, 1894, and was graduated in electrical engineering from Drexel Institute of Technology in 1916. Following graduation he was employed by the Philadelphia Electric Company as an engineering assistant, and in 1918 became assistant chief electrical designer. He was appointed chief electrical designer in 1925 and assumed his present position in 1929. He has also served on the committee on protective devices (chairman 1930–32) and the meetings and papers (now technical program) committee, and as executive secretary of the Middle Eastern District.

H. F. Harvey, Jr. (A'19) electrical engineer, Newport News Shipbuilding and Drydock Company, Newport News, Va., has been appointed chairman of the AIEE committee on applications to marine work for the year 1939–40. He has been a member of that committee and its predecessor, the marine committee, since 1920. Born at Cedar Bridge, N. J., October 12, 1888, he was graduated in electrical engineering from Pratt Institute in 1908. During the next year he was employed by the H. Krautz Manufacturing Company, Brooklyn, N. Y., on design work. From 1909 to 1919 he was employed in the switchboard engineering department of General Electric Company, Schenectady, N. Y., specializing on marine work, particularly electric propulsion of ships. He was employed by the Newport News Company in 1919 as engineer in the electrical division, and is now in charge of all electrical design work on ships.

E. J. O'Connell (A'25, M'36) telephone engineer, American Telephone and Telegraph Company, New York, N. Y., has been appointed chairman of the AIEE committee on communication. He has been a member of the committee since 1931. Born at Chicago, Ill., February 28, 1902, he received the degree of bachelor of science at Northwestern University in 1924. During the following year he was employed by the American Telephone and Telegraph Company on the construction forces building the first telephone cable between New York and Chicago. From 1925 to 1928 he was on the staff of the chief engineer, Illinois Bell Telephone Company, Chicago, and since then has been with the American Telephone and Telegraph Company in New York as technical specialist on protection and inductive co-ordination.

B. R. Teare, Jr. (A'29, M'36) formerly assistant professor of electrical engineering, Yale University, New Haven, Conn., has been appointed to the faculty of Carnegie Institute of Technology, to direct a newly organized program of graduate study in electrical engineering. A native (1907) of Menomonie, Wis., he received the degrees of bachelor of science (1927) and master of science (1928) from the University of Wisconsin and that of doctor of engineering from Yale University. He was employed by General Electric Company, Schenectady, N. Y., from 1929 to 1933, when he was appointed to the Yale faculty. He is a member of the Society for the Promotion of Engineering Education, Sigma Xi, Tau Beta Pi, and Eta Kappa Nu, and has served on technical committees of the AIEE.

Zay Jeffries (M'36) technical director, incandescent lamp department, General Electric Company, Cleveland, Ohio, has been elected to membership in the National Academy of Sciences. Born April 22, 1888, at Willow Lake, S. Dak., he received the degrees of bachelor of science and metallurgical engineer from the South Dakota School of Mines, and the degree of doctor of science from Harvard University. He has been a consultant for the incandescent lamp department of General Electric since 1914, and technical director since 1936. He is a member of the American Institute of Mining and Metallurgical Engineers, American Society of Metals, American Physical Society, Faraday Society, British Iron and Steel Institute, and Institute of Metals.

F. W. Appleton (M'28) has retired as assistant vice-president of the New York (N. Y.) Telephone Company. Born April 12, 1887, at Lake Henry, S. Dak., he received the degree of bachelor of science in electrical engineering from the University of Michigan. He was employed by the New York Telephone Company in 1909 as plant and toll engineer, and has continued with the company ever since, becoming division plant engineer in 1922, division construction superintendent 1925, division plant superintendent 1926, assistant general plant manager 1927, chief engineer Bronx-Westchester area 1927, general plant manager 1928, and vice-president and general manager, Long Island area, 1933. He became assistant vice-president in charge of staff engineering in 1933, and since April 1939 has been in charge of staff inventory and appraisal.

G. J. Fiedler (A'32) has been appointed associate professor of electrical engineering at Montana State College, Bozeman. He was formerly a member of the electrical-engineering department of Union College, Schenectady, N. Y. A native (1904) of Bushton, Kans., he received the degrees of bachelor of science in electrical engineering from Kansas State College (1926), master of science, University of Kansas (1932), electrical engineer, Kansas State College (1936). He was in the test department of General Electric Company at Pittsfield, Mass., and Schenectady, N. Y., 1926–28, and 1928–31 was associated with the Radio Corporation of America. He was laboratory assistant and later instructor at the University of Kansas, Lawrence, and director of the Albany, Schenectady, and Troy Collegiate Centers of the New York State Teachers' College, before going to Union in 1935.

E. W. Hamlin (A'35) has been appointed professor of electrical engineering at the University of Texas, Austin, where he will have charge of communication courses. Born July 21, 1905, at New York, N. Y., he received from Union College the degrees of bachelor of science, 1926; master of science, 1928; doctor of philosophy in electrical engineering, 1932. After spending the summer of 1926 in the test department of General Electric Company, Schenectady, N. Y., he became an instructor in electrical engineering at Union, at the same time carrying on graduate study. In 1935 he went to the University of Kansas, Lawrence, as assistant professor of electrical engineering, becoming associate professor in 1937. He is a member of the Society for Promotion of Engineering Education, Sigma Xi, and Eta Kappa Nu.

A. P. Gompf (A'27) has been appointed chief engineer, Chesapeake and Potomac Telephone Company of Virginia, Richmond. Born August 28, 1892, at Howardville, Md., he was graduated from Baltimore Polytechnic Institute and received the degree of bachelor of science in education from Columbia University. He was employed as an electrical draftsman by the Bethlehem Steel Company, Sparrow's Point, Md., in 1917, then went into military service, and 1919–20 served as apprentice instructor in the electrical and mechanical divisions, Panama Canal. He went with the Chesapeake and Potomac Company, Washington, D. C., in 1920 as an engineering assistant, becoming inventory and costs engineer of

the companies in 1927, and staff engineer, department of operation, in 1929, which position he held until his present appointment.

F. E. Brooks (A'38) has been appointed chief engineer of the Bronx-Westchester area, New York Telephone Company, New York, N. Y. He was born January 27, 1890, at Kansas City, Mo., and received the degrees of bachelor of science (1912) and electrical engineer (1921) from the Case School of Applied Science. He entered the engineering department of the New York Telephone Company in 1912 and except for military service 1917–19, has been with the company continuously. He was appointed engineer of plant extension, Bronx-Westchester area, in 1927, and in 1935 was given the same position in the Manhattan area, his duties being extended in 1937 to include electrical-engineering supervision of transmission design and maintenance. He is a member of Eta Kappa Nu.

B. W. Creim (A'20, F'31) has been appointed principal engineer in charge of the project construction section, engineering division, Bonneville Dam project, Portland, Ore. For the past three years he has been principal engineer for the Rural Electrification Administration, Washington, D. C., having charge of design and construction of rural systems in the western states. He was electrical engineer for the City of Los Angeles (Calif.) Bureau of Power and Light 1919–27 and chief electrical engineer for the Modesto (Calif.) Irrigation District from 1927 until 1936.

W. V. B. Van Dyck (A'01, M'31) assistant to the president, International General Electric Company, Schenectady, N. Y., has been awarded the Order of the Southern Cross by the government of Brazil, in recognition of his services in promoting good will between Brazil and the United States. Mr. Van Dyck was associated with General Electric in Rio de Janeiro, Brazil, from 1911 through 1926, as special representative in Brazil, managing director of General Electric of Brazil, and president of General Electric of South America. He returned to the United States in 1927 to become manager of the Schenectady office of International General Electric.

F. J. Leerburger (A'28, M'35) formerly senior assistant engineer with Maurice R. Scharff, consulting engineer, New York, N. Y., has been appointed principal valuation engineer for the New York State Public Service Commission. Mr. Leerburger, who holds the degrees of bachelor of arts, bachelor of science, and electrical engineer from Columbia University, was an engineer for the Duquesne Light Company, Pittsburgh, Pa., and the Foxboro Company, New York, N. Y., before joining the Scharff staff in 1932.

C. H. Buchanan (A'37) formerly design engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been appointed instructor in electrical engineering, Iowa State College, Ames. He had been with Westinghouse since 1936, except for a leave of absence in 1937 during which he taught in the electrical-engineering department of Carnegie Institute of Technology, Pittsburgh.

W. F. Daly (A'20) has been placed in charge of the St. Louis (Mo.) district office of Allis-Chalmers Manufacturing Company. He had been connected with the Chicago office of the company since 1924, and before that time was with the Crocker-Wheeler Company in Chicago, Ill., and Ampere, N. J.

Daniel Silverman (A'33) geophysicist, Tulsa, Okla., has for some time been a member of the staff of the laboratory of the Western Geophysical Company and the Stanolind Oil and Gas Company, Tulsa, in charge of design, construction, test, and servicing of all geophysical instruments.

B. J. Rowan (A'28) has been appointed assistant to the manager of the publicity department, General Electric Company, Schenectady, N. Y., in charge of the administrative and production division. Since 1930 he had been district manager of the publicity department in New York, N. Y.

Frederic Attwood (M'27) vice-president, Ohio Brass Company, New York, N. Y., has been made a chevalier of the Legion of Honor of France, in recognition of military services and his activities in the International Conference on High-Voltage Electrical Systems (CIGRÉ), in which he is president of the American delegation and a vice-president of the Conference.

F. A. Faron (A'21, M'27) has been appointed assistant manager of the industrial department, New York district, General Electric Company. He was formerly manager of the New Haven, Conn., office of the company, with which he has been associated since 1916.

K. T. Compton (F'31) president of Massachusetts Institute of Technology, Cambridge, has been appointed chairman of a committee named by the National Association of Manufacturers to select outstanding inventors to be honored as "Modern Pioneers."

W. F. Nimmo (A'30, M'35) general engineering department, Virginia Electric Power Company, Richmond, has been appointed chairman of the Edison Electric Institute's committee on transmission and distribution for 1939–40.

J. H. Smith (A'32) has joined the teaching staff of the electrical-engineering department, University of Illinois, Urbana. He was formerly professor of electrical engineering at Detroit Institute of Technology, Detroit, Mich.

L. V. Banta (A'34) formerly sales service engineer, Edison Storage Battery Supply Company, San Francisco, Calif., has been transferred to the sales engineering department, storage battery division, Thomas A. Edison, Inc., West Orange, N. J.

C. R. Smith (A'39) formerly a student engineer with the General Electric Company, Schenectady, N. Y., has been appointed instructor at the Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia.

D. S. Smith (A'33) formerly power apparatus engineer, Northern Electric Company, Ltd., Montreal, Que., Can., has joined the staff of the National Research Council, department of physics and electrical engineering, at Ottawa, Can.

E. E. Powell (A'37) has been appointed district engineer of Southwestern Bell Telephone Company, with headquarters at St. Joseph, Mo. He was formerly exchange inventory supervisor, Wichita, Kans., and chairman of the AIEE Wichita Section.

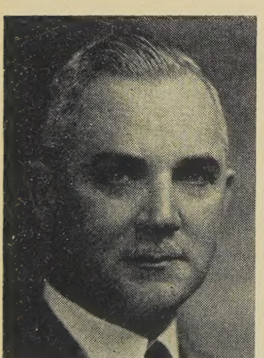
R. H. Anthony (A'17) sales engineer, Boston, Mass., has been appointed New England correspondent of Sweitzer and Conrad, Inc. He also represents the G. and W. Electric Specialty Company and the Electroline Company.

H. C. Ellmaker (A'35) has become assistant electrical engineer, United States Engineer's Office, Los Angeles, Calif. He was formerly recording engineer with the engineering firm of Batsley and Phillips, Los Angeles.

W. E. Haywood (M'36) formerly district plant superintendent, American Telephone and Telegraph Company, Dallas, Tex., has been transferred by the company to New York, N. Y., as engineer.

R. W. Ahlquist (A'35) formerly assistant professor of electrical engineering, University of Pittsburgh, Pittsburgh, Pa., has been appointed assistant professor of electrical engineering, Iowa State College, Ames.

F. A. Engel, Jr. (A'39) has been employed by the Speer Carbon Company Laboratories, St. Mary's, Pa.



F. E. BROOKS

A. P. GOMPF

Bachrach

E. J. O'CONNELL

G. F. Tracy (A'26) who has been associate professor of electrical engineering at the University of Toronto, Toronto, Can., has returned to his former position as associate professor of electrical engineering, University of Wisconsin, Madison.

H. L. Wallau (A'00, F'13) electrical engineer, Cleveland Electric Illuminating Company, Cleveland, Ohio, has been appointed chairman of the Edison Electric Institute's committee on electrical equipment for the year 1939–40.

E. F. Weaver (A'26) formerly superintendent, Lehigh division, Pennsylvania Power and Light Company, Allentown, Pa., has been appointed superintendent of transmission of the company, with headquarters at Hazelton, Pa.

G. M. S. Stein (M'38) formerly electrical engineer, Federal Machine and Welder Company, Warren, Ohio, has entered the transformer engineering department of Westinghouse Electric and Manufacturing Company, Sharon, Pa.

David Younger (A'37) who has been district plant engineer, American Telephone and Telegraph Company, Buffalo, N. Y., has been transferred by the company to the office of the general plant superintendent, New York, N. Y.

E. W. Kimbark (A'27, M'35) has been appointed assistant professor of electrical engineering, Northwestern University, Evanston, Ill. He formerly held the same position at Brooklyn Polytechnic Institute, Brooklyn, N. Y.

J. R. Fritz (A'38) former assistant district superintendent, New Jersey Power and Light Company, Flemington, has become an instructor in electricity at the Wyomissing Polytechnic Institute, Wyomissing, Pa.

R. E. Ehrenfeld (M'24) formerly small-motor designer, Westinghouse Electric and Manufacturing Company, Lima, Ohio, has been employed as electrical engineer by the Apex Electrical and Manufacturing Company, Cleveland, Ohio.

Alfred Skrobisch (A'36) formerly application engineer, Tung-Sol Lamp Works, Inc., Newark, N. J., has been employed in the control engineering department, Curtiss Propeller division, Clifton, N. J., of the Curtiss-Wright Corporation.

S. O. Evans (A'33) formerly engineer, General Electric Company, Pittsfield, Mass., has been appointed assistant professor of electrical engineering, Ohio State University, Columbus.

J. T. Henderson (A'32) formerly electrical engineer, General Electric Company, Lynn, Mass., has been employed as electrical-engineering draftsman, Central New York Power Company, Syracuse, N. Y.

C. F. Kettering (A'04, F'14) vice-president in charge of research, General Motors Corporation, Dayton, Ohio, received the honorary degree of doctor of science from Dartmouth College in June 1939.

W. R. Smith (M'18, F'30) safety engineer, Public Service Electric and Gas Company, Newark, N. J., has been appointed chairman of the committee on accident prevention of the Edison Electric Institute for 1939–40.

T. J. Woth (A'33) engineer, Westinghouse Electric and Manufacturing Company, has been transferred from the Buffalo, N. Y., office of the company to the Atlanta, Ga., office.

L. E. Cook (A'25, M'35) formerly supervisor of distribution, Texas Power and Light Company, Dallas, has been employed as electrical engineer by Ebasco Services, Inc., New York, N. Y.

J. M. Noy (A'37) has been employed as research chemist and metallurgist by the Foote Mineral Company, Inc., Philadelphia, Pa.

Obituary

Arnold Honegger (A'15, M'28) vice-president, Business Research Corporation, Chicago, Ill., died June 20, 1939. He was born November 1, 1879, at St. Gallen, Switzerland, and was graduated from the Institute for Electrical and Mechanical Engineers, Mitweida, Saxony, Germany, in 1902. He was employed for a year by the General Electric Company, Schenectady, N. Y., on designing and drafting transformers and switchboards, and from 1903 to 1907 was engaged in design and construction for the St. Louis and Suburban Railway, St. Louis, Mo.; the National Construction Company, St. Louis; the Chicago City Railway Company, Chicago, Ill.; and the Electrical Installation Company, Chicago. He was employed from 1907 to 1911 by the Falkenau Electrical Construction Company of Chicago, and in 1911 entered the employ of the International Harvester Company, by which organization he was sent to Russia, where he represented that company and others until 1915. He was engaged in construction and engineering for A. M. Hewes and Company, Chicago; Nebraska Electric Company, Omaha; Winslow Brothers Company, Chicago; and Sessions Engineering Company, Chicago, until 1920, when he became assistant director of the Business Research Corporation. He continued with that organization until his death.

Charles William Godson Little (A'96) retired chief engineer, British Electrical Federation, London, Eng., died recently, according to information received at Institute headquarters. He was born at Heckington, Lincolnshire, Eng., in 1866, and was educated at Finsbury Technical College. In 1889 he became associated with the Thomson-Houston International Electric Company, Boston, Mass., was transferred in 1891 to the French Thomson-Houston Company, Paris, and in 1893 joined the newly formed British Thomson-Houston Company, Ltd., later becoming chief of the construction department. In 1899 he joined the British Electric Traction Company as chief executive electrical engineer, being connected with lighting, power, and traction undertakings in England and also in New Zealand and India. He later became associated with the British Electrical Federation, and in that connection was sent to Brazil, Argentine, and Russia. He retired as chief engineer in 1930. He was a member of The Institution of Electrical Engineers of Great Britain.

Charles W. Davis (M'29) president and general manager, Dallas Power and Light Company, Dallas, Tex., died September 16, 1939. He was born at Sandusky, Ohio, November 10, 1874, and attended Ohio State University. During the years 1894 to 1900 he was associated with the Maryland Electric Company, Brush Electric Company, and Westinghouse Electric Company, all of Baltimore, Md., the Fort Wayne, Ind., Electric Company, and the Warren Electric Company, Sandusky. During the next two years he was engaged in the construction and operation of lighting plants in Texas, and from 1902 to 1904 sold equipment for the Southwestern Electric Engineering and Construction Company, Dallas. He became district manager of the Westinghouse Electric and Manufacturing Company in Dallas in 1904, continuing in that position until 1919 when he became vice-president and general manager of the Dallas Power and Light Company. He was made president of the company in 1930.

Leo Dorsey Firman (A'06, M'13) consulting engineer, Leesburg, N. J., died recently, according to information just received at Institute headquarters. He was born January 2, 1864, at Carversville, Pa. He began his electrical career in 1881 as telegraph operator, working as operator and assistant wire chief for various companies. In 1887 he was employed by the Western Union Telegraph Company, Philadelphia, Pa., as operator, later becoming wire chief. He was employed in 1895 as an inspector by the City of Philadelphia Electrical Bureau, in 1905 became assistant inspector of electric lighting, and in 1908 assistant chief of the Bureau. In 1916 he went with Stockwell, Wilson, and Linvill, Philadelphia, later becoming appraisal engineer for the firm, and subsequently entered independent practice as a consulting electrical engineer.

Roy Bingham Ashbrook (A'20, M'30) communication engineer, Southern California Edison Company, Ltd., Los Angeles, Calif., died August 15, 1939. He was born July 28, 1890, at Kansas City, Mo., and educated there. From 1906 through 1909, he was employed by Western Electric Company and the Missouri and Kansas Telephone Company, in Kansas City. He was with the Pacific Telephone and Telegraph Company, Los Angeles, Calif., 1910–12, and in 1913 entered the employ of Southern California Edison. After four years with the test department he was made responsible for the company's communication services. He supervised the growth of the communications system, designing much equipment for special purposes. He was a member of the Institute of Radio Engineers.

Richard Henry Silbert (A'17, M'27) industrial service representative, Philadelphia Electric Company, Philadelphia, Pa., died recently, according to information received at Institute headquarters. He was born at Philadelphia, Pa., July 28, 1880. In 1900 he was employed by the Bell Telephone Company of Philadelphia, and in 1902 by Western Electric Company, installing telephone facilities in Philadelphia and adjacent areas. He was employed by the Philadelphia Electric Company in 1904, spent 1905–06 with the West Jersey and Seashore Railroad, and returned to Philadelphia Electric in 1906, continuing with the company until his death. He was successively inspector, special inspector, assistant superintendent of inspection, and industrial service representative.

William Trudgian (A'27) special representative, Westinghouse Electric and Manufacturing Company, Denver, Colo., died September 19, 1939, at Craig, Colo. He was born in Galena, Ill., December 22, 1881, and received the degree of bachelor of science in electrical engineering from the University of Colorado in 1907. He entered the employ of the Westinghouse company the same year, and except for one year, 1918–19, spent as an inspector for the United States Government, continued with the company the rest of his life. He was manager of the district including Colorado, Wyoming, and New Mexico, 1930–35, and since 1935 had been special representative in the same district.

Sanford Bennett Waring (A'35) assistant electrical-engineering draftsman, Signal Service at Large, United States War Department, Atlanta, Ga., died recently, according to information received at Institute headquarters. He was born at Sandwich, Mass., October 30, 1912, and received the degree of bachelor of science in electrical engineering from the University of Florida in 1934. He was employed as a draftsman by the Florida State Road Department, Ocala; in the City Engineer's office, Gainesville, Fla., on a Federal public buildings survey in Gainesville, and later as office engineer of the City Engineer's office, before taking the Signal Service position.

Membership

Recommended for Transfer

The board of examiners, at its meeting on October 19, 1939, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Booth, Jesse James, assistant superintendent of maintenance, Carnegie-Illinois Steel Corporation, Duquesne, Pa.
Green, C. W., technical representative in Europe, American Telephone and Telegraph Co., and Bell Telephone Laboratories, Inc., London, Eng.
Hill, C. F., research physicist, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Scott, R. C., vice-president and chief engineer, Mutual Boiler Insurance Company of Boston, Mass.

4 to Grade of Fellow

To Grade of Member

Cooper, J. B., electrical engineer, General Electric Company, Pittsfield, Mass.
Dickinson, H. F., electrical engineer, Anaconda Wire and Cable Company, Hastings-on-Hudson, N. Y.
Hoover, P. L., head of electrical engineering department, Case School of Applied Science, Cleveland, Ohio
Keen, A. H., local office manager, General Electric Company, Fort Worth, Tex.
Petrie, A. E., power development engineer, Bell Telephone Laboratories, Inc., New York, N. Y.
Sine, E. R., electrical engineer, Rome Cable Corporation, Rome, N. Y.
Strang, H. E., managing engineer, large oil circuit breaker division, General Electric Company, Philadelphia, Pa.

7 to Grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by geographical Districts. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before November 30, 1939, or January 31, 1940, if the applicant resides outside of the United States or Canada:

United States and Canada

1. North Eastern

Arnold, R. E. (Member), General Electric Company, West Lynn, Mass.
Paul, J. E., Union College, Schenectady, N. Y.
Walter, B. M., General Electric Company, Pittsfield, Mass.

2. Middle Eastern

Angier, M. S., Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.
Campbell, D. A., Jr., Pennsylvania Power and Light Company, Allentown, Pa.
Cottle, C. H., The Scranton Electric Company, Scranton, Pa.
Davis, H. L., Consolidated Gas Electric Light and Power Company, Baltimore, Md.
Johnson, C. H., Line Material Company, Allentown, Pa.
Kiss, M. A., Hickok Electrical Instrument Company, Cleveland, Ohio.
Mancill, R. D., I-T-E Circuit Breaker Company, Philadelphia, Pa.
Northup, V. E., The Scranton Electric Company, Scranton, Pa.
Park, R. B., The Scranton Electric Company, Scranton, Pa.
Poole, L. C., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Sweets, J. E., American Telephone and Telegraph Company, Cleveland, Ohio.
Thompson, H. H. (Member), Westinghouse Electric and Manufacturing Company, Washington, D. C.
Waxman, A. S., Bethlehem Steel Company, Sparrows Point, Md.

3. New York City

Baker, R. (Member), Long Island Lighting Company, Mineola, N. Y.
Kaiser, E. T., Prudential Insurance Company of America, Newark, N. J.
LeVino, R. B., Interborough Rapid Transit Company, New York, N. Y.
Lichty, H. F., Eifler Electric, Inc., Union City, N. J.
Lindsay, N. W., Westchester Lighting Company, Mount Vernon, N. Y.
Petersen, A. H. (Member), Columbia Broadcasting System, New York, N. Y.
Scott, C. F., Western Electric Company, Inc., Kearny, N. J.
Thayer, P. H., Jr., Bell Telephone Laboratories, Inc., New York, N. Y.
Van Tassell, W. H., Westchester Lighting Company, Mount Vernon, N. Y.

4. Southern

Carpenter, R. C., Electrical Engineering and Repair Company, Atlanta, Ga.
Sittloh, C. F., Alabama Power Company, Birmingham.

5. Great Lakes

Curtis, F., American Brass Company, Detroit, Mich.
Goodell, P. H. (Member), C. M. Hall Lamp Company, Detroit, Mich.
Newman, M., University of Minnesota, Minneapolis.
Oerman, H. W., Public Service Company of Northern Illinois, Chicago, Ill.
Rupprecht, W. J. L., The Dow Chemical Company, Midland, Mich.

7. South West

Barron, J. P., Dallas Power and Light Company, Dallas, Tex.
Baumann, L., Square D Company, Houston, Tex.
Butler, J. J., Westinghouse Electric and Manufacturing Company, St. Louis, Mo.
Hull, S. B., Southwestern Bell Telephone Company, Dallas, Tex.
McLeod, L. W., Westinghouse Electric and Manufacturing Company, St. Louis, Mo.
Nielsen, L., Southwestern Bell Telephone Company, Oklahoma City, Okla.
Price, E. R., Westinghouse Electric and Manufacturing Company, Dallas, Tex.
Schultz, L. H., Southwestern Bell Telephone Company, St. Louis, Mo.
Wise, E. C., General Electric Company, El Paso, Tex.

8. Pacific

Barneby, G. L., Southern California Edison Company, Wilmington, Calif.
Bustard, W. B., Westinghouse Electric and Manufacturing Company, Phoenix, Ariz.
Craig, F. D., 1021 Mariposa Avenue, Berkeley, Calif.
Harrison, R. C. (Member), Central Arizona Light and Power Company, Phoenix, Ariz.
Hickey, F. W., Jr., Public Works Administration, San Francisco, Calif.
Jones, W. W. (Member), Fog Nozzle Company, Los Angeles, Calif.

9. North West

Christensen, L. J., West High School, Salt Lake City, Utah.

10. Canada

Gray, J. B., Georgetown Hydro Electric Power Commission, Georgetown, Ont.
Otis, A. M., Hamilton Hydro Electric System, Hamilton, Ont.
Stockman, E. O., C. A. Parsons and Company, Ltd., Toronto, Ont.

Total, United States and Canada, 51

Elsewhere

Angus, J. H. (Member), Electricity Department, Port Elizabeth, South Africa.
Shilcock, A. E. (Member), Cable and Wireless (W. I.), Ltd., San Juan, Puerto Rico.

Total, elsewhere, 2

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the addresses as they now appear on the Institute record. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Crawford, Wade P., Box 364, Coeur D'Alene, Idaho.
Doherty, Joseph F., 901 Hill St., Wilkinsburg, Pa.
Evans, David T., Box 194, Anyox, B. C., Can.
Hall, John R., c/o Patrick Tyrrell Drilling Co., Cotton Exchange Bldg., Houston, Texas.
Hollifield, Ray, 5118 Milam St., Dallas, Texas.
Keiser, M., 1841 Broadway, New York, N. Y.
Lovett, Morris, Diehl Manufacturing Company, Elizabethport, N. J.
McCarthy, C. C., c/o Westinghouse Electric and Manufacturing Co., 814 Ellicott Square, Buffalo, N. Y.
O'Fiel, J. C. Dudley, Jr., 1214 Chartres St., Houston, Texas.
Pyne, Arnold N., 627 Third St., Niagara Falls, N. Y.
Sanchez, Hector M., 12 De Diegos Ave., Santurce, Puerto Rico.
Shimp, Robert P., 3749 N. Gratz St., Pittsburgh, Pa.
Taylor, Richard V., Hotel Wood, Jefferson & Clinton St., Syracuse, N. Y.
Teuscher, F. P., Apto. 1003, Mexico, Mex.

14 Addresses Wanted

Engineering Literature

New Books in the Societies Library

Electrical engineers may be interested in the following new books, which are among those recently received at the Engineering Societies Library, New York, N. Y. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the preface of the book in question.

PETROLEUM PRODUCTION ENGINEERING, OIL FIELD EXPLOITATION. By L. C. Uren. Second edition. New York and London, McGraw-Hill Book Company, 1939. 756 pages, illustrated, 9 1/2 by 6 inches, cloth, $5.00. Revised and extended edition of the part of "Petroleum Production Engineering" that discusses oil-field exploitation. Affords a survey of the technology of oil production, covering methods and equipment and the physical principles, that control the recovery of petroleum from its reservoir rocks. Each chapter has a selected list of references.

ATOMS IN ACTION, THE WORLD OF CREATIVE PHYSICS. By G. R. Harrison. New York, William Morrow and Company, 1939. 370 pages, illustrated, 9 by 6 inches, cloth, $3.50. A presentation of what modern physicists think and do, and of some applications of their work in daily life.

ENGINEERING PHYSICAL METALLURGY. By R. H. Heyer. New York, D. Van Nostrand Company, 1939. 549 pages, illustrated, 9 by 6 inches, cloth, $4.50. Intended for those making their first acquaintance with engineering metals and alloys. A wide range of materials is discussed, including pure metals and alloys, processes of hot and cold reduction, heat treatment, welding machining, and so forth. Each chapter has a bibliography.

MATHEMATICS OF STATISTICS, Parts 1 and 2. By J. F. Kenney. New York, D. Van Nostrand Company, 1939. Part 1, 248 pages; Part 2, 202 pages, diagrams, etc., 9 by 6 inches, cloth, $4.00. An elementary textbook that calls for no mathematics beyond the ordinary freshman course in college algebra, this work introduces the fundamental principles and concepts that underlie the applications of statistics in various fields.

A MUSICAL SLIDE RULE. By L. S. Lloyd. London and New York, Oxford University Press, 1938. 25 pages, diagrams, tables, 9 by 6 inches, paper, $0.75. This booklet is intended as an introduction to the study of the musical scale employed by composers. Describes the differences between the scale of the tuned keyboard instrument and that played on a stringed instrument or sung. The reasons for the discrepancies are explained and directions are given for determining these discrepancies by means of a simple slide rule which accompanies the pamphlet.

PHYSICAL AND DYNAMICAL METEOROLOGY. By D. Brunt. Second edition. Cambridge, England, University Press; New York, The Macmillan Company, 1939. 428 pages, diagrams, etc., 10 by 7 inches, cloth, $6.75. Aims to provide English-speaking students with a textbook, suitable for postgraduate study, which will represent our present knowledge of theoretical meteorology as completely as possible. The new edition has been extended and in part rearranged.

ALTERNATING CURRENTS. By C. E. Magnusson. Fifth edition. New York and London, McGraw-Hill Book Company, 1939. 719 pages, illustrated, 9 by 6 inches, cloth, $5.00. This textbook presents the basic principles of alternating currents and their application to electric-power engineering. Revised to represent current conditions.

THE DISEASES OF ELECTRICAL MACHINERY. By G. W. Stubbings. New York, Chemical Publishing Company, 1939. 219 pages, diagrams, 8 by 5 inches, cloth, $3.00. Manual for power-plant engineers and electricians. The defects that arise in the operation of electrical machinery are discussed, their underlying causes explained, and practical directions given for their location and rectification.

VAPOR CHARTS AND SPECIAL TABLES FOR TURBINE CALCULATIONS. By F. O. Ellenwood and C. O. Mackey. New York, John Wiley and Sons, 1939. 43 pages, charts, tables, 11 by 8 inches, cloth, $2.50. These vapor charts replace the "steam charts" published by Mr. Ellenwood in 1914. The book form of chart is retained, but the tables for steam have been greatly extended and improved, and charts showing the thermodynamic properties of water, ammonia, dichlorodifluoromethane (freon-12), and mixtures of air and water vapor have been added.

ELECTRICITY TODAY. (The Pageant of Progress.) By T. B. Vinycomb. New York and London, Oxford University Press, 1939. 192 pages, illustrated, 9 by 6 inches, cloth, $1.75. Gives nontechnical readers an account of the way electricity is produced and distributed and of its uses in daily life. Heating, lighting, and methods of communication are described in terms of current practice.

ATM (ARCHIV FÜR TECHNISCHES MESSEN). Lieferungen 94–96, April 1–June 1939. Munich and Berlin, R. Oldenbourg, 1939. Illustrated, 12 by 8 inches, paper, 1.50 rm. each. Three numbers of a monthly publication containing classified articles upon various types of apparatus and methods for technical measurements; also some descriptions of specific instruments manufactured by German companies.

Great Britain, Department of Scientific and Industrial Research. REPORT 1937–38. London, His Majesty's Stationery Office, 1939. 203 pages, charts, 10 by 6 inches, paper, 3s. (obtainable from British Library of Information, 50 Rockefeller Plaza, New York, $0.90). Reviews the work of the various committees and associations and so affords a general survey of the scientific and industrial research work carried out in Great Britain during the year. Appendices give directories of the departments and associations and their officers, lists of the publications of the year, expenditures, and so on.

HEATING AND AIR CONDITIONING. By J. R. Allen and J. H. Walker. Fifth edition. New York and London, McGraw-Hill Book Company, 1939. 593 pages, illustrated, 9 by 6 inches, cloth, $4.50. Presents the theory underlying heating and air conditioning, together with practical information upon design and equipment. Adapted for use in engineering schools or for home study. Revised and enlarged edition.

INDUSTRIAL ELECTRICITY, Part 1. By C. L. Dawes. Second edition. New York and London, McGraw-Hill Book Company, 1939. 387 pages, illustrated, 8 by 6 inches, cloth, $2.20. For use in technical high schools and other schools not of collegiate grade where elementary electrical engineering is taught. The fundamentals of electrical engineering are presented and their industrial applications discussed. Revised to accord with current practice.

PATENTS AND THE PUBLIC INTEREST. By H. A. Toulmin. New York and London, Harper Brothers, 1939. 205 pages, illustrated, 9 by 6 inches, cloth, $2.50. Surveys our patent system critically and suggests lines of improvement. Discusses the reasons for the system, the relation between patents and such public problems as patent pools, unemployment, and patent suppression, and analyzes various proposals for reform. The final section describes the results of various modern inventions.

RECLAMATION 1902–1938, A SUPPLEMENTAL BIBLIOGRAPHY. (Regional Checklist No. 6, May 1939.) Compiled by J. J. Gaul at the Bibliographical Center for Research, Rocky Mountain Region, the Denver Public Library, Denver, Colo., 1939. 98 pages, manifold copy, 11 by 9 inches, cardboard, $1.00. Includes references on land reclamation not included in the three best known bibliographies devoted to that subject. About 1,500 references, arranged by author, with indexes by states, projects, and dams.

STEAM, AIR, AND GAS POWER. By W. H. Severns and H. E. Degler. Third edition. New York, John Wiley and Sons, 1939. 511 pages, illustrated, 9 by 6 inches, cloth, $4.00. This textbook presents "illustrations, descriptions, and underlying theory of construction, application, and performance of modern heat power plants and their correlated equipment." Numerous changes in this edition reflect recent progress.

TERRESTRIAL MAGNETISM AND ELECTRICITY. (Physics of the Earth, VIII) edited by J. A. Fleming. New York and London, McGraw-Hill Book Company, 1939. 794 pages, illustrated, 10 by 7 inches, cloth, $8.00. Eighth of a series of monographs upon the physics of the earth prepared by specialists under the direction of various committees of the National Research Council. This volume reviews our knowledge of the earth's magnetic and electrical phenomena. Magnetic surveys and instruments, magnetic prospecting, atmospheric electricity, the outer atmosphere, the aurora polaris, and thunderclouds are among the subjects presented. Bibliography of over 1,500 items.

WAVE-LENGTH TABLES With Intensities in Arc, Spark, or Discharge Tube of More Than 100,000 Spectrum Lines Most Strongly Emitted by the Atomic Elements Under Normal Conditions of Excitation Between 10,000 A. and 2,000 A., Arranged in Order of Decreasing Wave Lengths. Measured and compiled under the direction of G. R. Harrison by staff members of the spectroscopy laboratory of the Massachusetts Institute of Technology, assisted by the Works Progress Administration. Cambridge, Mass., Technology Press; New York, John Wiley and Sons, 1939. 429 pages, illustrated, 11 by 8 inches, cloth, $15.00. The most extensive catalog that has yet appeared; this volume, valuable to all, is sufficiently described by its title.

WINTER AIR CONDITIONING; FORCED WARM-AIR HEATING. Edited by S. Konzo. Columbus, Ohio, National Warm-Air-Heating and Air-Conditioning Association, 1939. 532 pages, illustrated, 9 by 6 inches, cloth, $3.00. Based largely upon the research work in forced-air heating conducted in the warm-air-heating research residence at the University of Illinois since 1932. From this and supplementary data a comprehensive survey of the present status of the design, installation, and operation of the forced-air heating plant is gained. Extensive calculations, both theoretical and actual, are included for all phases of the subject.

PHYSIK. By P. Wessel and V. R. von Paar. Munich, Ernst Reinhardt, 1938. 514 pages, diagrams, etc., 8 by 5 inches, leather, 4.90 rm. This college textbook, which covers the customary topics included in physics courses, uses many illustrations and heavy line boxes around certain equations to clarify and emphasize important points. Contains a review section, test questions, with references to the appropriate sections of the text, and a detailed index.

SCHWEISSKONSTRUKTIONEN. (Einzelkonstruktionen aus dem Maschinenbau, Heft 9.) By R. Hänchen. Berlin, Julius Springer, 1939. 123 pages, illustrated, 11 by 8 inches, paper, 18.60 rm. The fundamentals of welding processes are covered in the first part of this work, including a discussion of materials and their weldability, the preparation of parts to be welded, seam formation, and graphic symbols representing various welds. The second and third parts consider calculations of welded joints for strength and safety, and the form of parts to be welded. In the final section actual jobs of welded construction are described and illustrated.

GREAT ENGINEERS. By C. Matschoss, translated by H. S. Hatfield. London, G. Bell and Sons, 1939. 381 pages, illustrated, 8 by 6 inches, cloth, 12s. 6d. This translation from the German contains short biographies of great engineers from antiquity to the 20th century. Emphasizes the human attributes of the men, their personalities, vicissitudes, and ultimate success.

COMPLEX VARIABLE AND OPERATIONAL CALCULUS WITH TECHNICAL APPLICATIONS. By N. W. McLachlan. Cambridge, England, University Press; New York, The Macmillan Company, 1939. 355 pages, diagrams, etc., 9 by 6 inches, cloth, $6.50. The author has based his theory of operational procedure on the Mellin inversion theorem, a combination of complex integration and the Laplace integral. The main treatment appears in part II. Part I contains an exposition of the theory of the complex variable, covering the technique of complex integration. In part III the application of the method to problems in various branches of technology is illustrated. Includes examples to be worked out, specific derivations, and list of references.

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